Choice Based Credit System (CBCS)

MURSHIDABAD UNIVERSITY

DEPARTMENT OF MATHEMATICS

POSTGRADUATE PROGRAMME

M. SC. COURSE IN MATHEMATICS

(Four Semesters)

(Courses effective from Academic Year 2021-22)

SYLLABUS OF COURSES TO BE OFFERED

M. Sc. Course in Mathematics
(Choice-Based Credit System)
Total Marks: 1000
(Total four-semester course carrying 250 marks in each semester)

Outline of the Choice Based Credit Semester System

Transaction Categories: CC: Core Course; **CB**: Choice Based Course; **E**: Elective Course; PW: Project Work

Evaluation Categories: SEE: Semester End Examination; **IA**: Internal Assessment

Course/Paper	Topics	Marks		Credit	Hrs/Wk
		SEE	IA		
SEMESTER I					
PG-MATH-CC-101	Algebra-I	40	10	4	4
PG-MATH-CC-102	Complex Analysis	40	10	4	4
PG-MATH-CC-103	Ordinary Differential Equations	40	10	4	4
PG-MATH-CC-104	Topology	40	10	4	4
PG-MATH-CC-105	Advanced Programming in C	40	10	4	6
SEMESTER II					
PG-MATH-CC-201	Algebra-II	40	10	4	4
PG-MATH-CC-202	Classical Mechanics	40	10	4	4
PG-MATH-CC-203	Measure Theory and Integration	40	10	4	4
PG-MATH-CC-204	Operations Research	40	10	4	4
PG-MATH-CC-205	Computer Practical (application of Matlab and typesetting software Latex)	40	10	4	6

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DETAILS OF COURSE:

SEMESTER I

Duration: 6 Months (Including Examinations) Total 20 credits (Marks: 250)

Course/Paper	Topics	Marks		Credit	Hrs/Wk
		SEE	IA		
SEMESTER I					
PG-MATH-CC-101	Algebra-I	40	10	4	4
PG-MATH-CC-102	Complex Analysis	40	10	4	4
PG-MATH-CC-103	Ordinary Differential Equations	40	10	4	4
PG-MATH-CC-104	Topology	40	10	4	4
PG-MATH-CC-105	Advanced Programming in C	40	10	4	6

M. Sc. Course in Mathematics
SEMESTER-I Course Code: PG-MATH-CC-101
Course title: Algebra-I Core Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 3:1:0

Group A (25 Marks)

Basic Algebra: Review of basic concept of Algebra: Permutations, combinations, pigeon-hole principle, inclusion-exclusion principle, derangements. Fundamental theorem of arithmetic, divisibility in Z, congruence's, Chinese Remainder Theorem, Euler's Ø- function, primitive roots.

Group Theory: Review of basic concepts of Group Theory: Groups, subgroups, normal subgroups, quotient groups Lagrange's Theorem.

Cyclic Groups, Permutation Groups and Groups of Symmetry: Sn, A_n D_n, Conjugacy Classes, Index of a Subgroup, Divisible Abelian Groups. Homomorphism of Groups, Normal Subgroups, Quotient Groups, Isomorphism Theorems, Cayley's Theorem. Generalized Cayley's Theorem, Direct Product and Semi-Direct Product of Groups, Fundamental Theorem (Structure Theorem) of Finite Abelian Groups (Statement and its application only), Cauchy's Theorem, Group Action, Sylow Theorems and their applications. Solvable Groups.

Normal and Subnormal Series, Composition Series, Solvable Groups and Nilpotent Groups, Jordan-Hölder Theorem (Statement and its application only).

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Group B (25 Marks)

Review of Vector Spaces: Vector spaces over a field, subspaces. Sum and direct sum of subspaces. Linear span. Linear dependence and independence. Basis.

Finite dimensional spaces. Existence theorem for bases in the finite dimensional case. Invariance of the number of vectors in a basis, dimension. Existence of complementary subspace of any subspace of a finite dimensional vector space. Dimensions of sums of subspaces. Quotient space and its dimension. Infinite dimensional vector spaces.

Matrices and Linear Transformations: Matrices and linear transformations, change of basis and similarity. Algebra of linear transformations. Change of basis. Isomorphism Theorems. Adjoint of linear transformations. Eigen values and eigenvectors of linear transformations. Determinants. Characteristic and minimal polynomials of linear transformations, Cayley Hamilton Theorem. Diagonalization of operators. Invariant subspaces. Canonical forms.

References:

1. Roman, S., Fundamentals of Group Theory: An Advanced Approach, Birkhauser, 2012.
2. Malik, D.S., Mordesen, J.M., Sen, M.K., Fundamentals of Abstract Algebra, The McGraw-Hill Companies, Inc, 1997.
3. Rotman, J., The Theory of Groups: An Introduction, Allyn and Bacon, Inc., Boston, 1973.
4. Rotman, J., A First Course in Abstract Algebra, Prentice Hall, 2005.
5. Pinter, Charles. C., A Book of Abstract Algebra, McGraw Hill, 1982.
6. Herstein, I.N., Topics in Abstract Algebra, Wiley Eastern Limited, 1975.
7. Gallian, J., Contemporary Abstract Algebra, Narosa, 2011.
8. Jacobson, N., Basic Algebra, I & II, Hindusthan Publishing Corporation, India.
9. Hungerford, T.W., Algebra, Springer.
10. Artin, M., Algebra, Prentice Hall of India, 2007.
11. Goldhaber, J.K., Ehrlich, G., Algebra, The Macmillan Company, Collier-Macmillan Limited, London.
12. Dummit, D.S., Foote, R.M., Abstract Algebra, Second Edition, John Wiley & Sons, Inc., 1999
13. Artin, M., Algebra, Prentice Hall of India, 2007.
14. Halmos, P.R., Finite Dimensional Vector Spaces, Springer, 2013.
15. Roman, S., Advanced Linear Algebra, Springer, 2007.
16. Curtis, C.W., Linear Algebra: An Introductory Approach, Springer (SIE), 2009.
17. Hoffman, K., Kunze, R., Linear Algebra, Prentice Hall of India, 1978.
18. Dummit, D.S., Foote, R.M., Abstract Algebra, Second Edition, John Wiley & Sons, Inc., 1999.
19. Apostol, T.M., Calculus Vol. I & II, John Wiley and Sons, 2011.

Rajib Mukherjee

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M. Sc. Course in Mathematics
SEMESTER-I
Course Code: PG-MATH-CC-102

Course title: Complex Analysis Core Course; Credit-4; Full Marks-50 Course wise Class (L+T+P): 3:1:0

Complex Differentiation: Review of Cauchy-Riemann equations, sufficient conditions for differentiability.

Complex Functions and Conformality: Stereographic projection, Analytic functions, Entire functions, Harmonic functions and Harmonic conjugates, Polynomial functions, Rational functions, Power series, Exponential, Logarithmic, Trigonometric and Hyperbolic functions, Branch of a logarithm, Conformal maps, Mobius Transformations.

Complex Integration: The complex integral (over piecewise $C1$curves), Cauchy's Theorem and Integral Formula, Power series representation of analytic functions, The difference between Real Analytic functions and C_∞ functions over R. Real Analyticity vs. Complex Analyticity. Morera's Theorem, Goursat's Theorem, Liouville's Theorem, Fundamental Theorem of Algebra, Zeros of analytic functions, Identity Theorem, Weierstrass Convergence Theorem (Statement only), Maximum Modulus Principle and its applications, Schwarz's Lemma, Index of a closed curve, Contour, Index of a contour, Simply connected domains, Cauchy's Theorem for simply connected domains.

Singularities: Definitions and Classification of singularities of complex functions, Isolated singularities, Uniform convergence of sequences and series, Laurent series, Casorati-Weierstrass Theorem (Statement only), Poles, Residues, Residue Theorem and its applications to contour integrals, Applications of Argument Principle, Applications of Rouche's Theorem.

References:

1. Sarason, D., Complex Function Theory, Hindustan Book Agency, Delhi, 1994.
2. Ahlfors, L.V., Complex Analysis, McGraw-Hill, 1979.
3. Rudin, W., Real and Complex Analysis, McGraw- Hill Book Co., 1966.
4. Hille, E., Analytic Function Theory (2 vols.), Gonn & Co., 1959.
5. Gamelin, T.W., Complex Analysis, Springer, 2001.
6. Bak, J., Newman, D.J., Complex Analysis, Springer, 2010.
7. Marsden, J.E., Hoffman, M.J., Basic Complex Analysis, Third Edition, W. H. Freeman and Company, New York, 1999.
8. Ponnusamy, S., Foundations of Complex Analysis, Narosa, 2008.
9. Conway, J.B., Functions of One Complex Variable, Second Edition, Narosa Publishing House, 1973.

Rajib Mukherjee

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M. Sc. Course in Mathematics
SEMESTER-I
Course Code: PG-MATH-CC-103
Course title: Ordinary Differential Equation
Core Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 3:1:0

Existence and Uniqueness: First order ODE, Initial value problems, Existence theorem, Uniqueness, basic theorems, Ascoli Arzela theorem, Theorem on convergence of solution of initial value problems, Picard - Lindelof theorem, Peano's existence theorem and corollaries.

System of ODE: Existence and uniqueness of solution of systems, Local existence, Non-local existence, Approximation and uniqueness, Existence and uniqueness for linear systems, linear homogeneous systems, Nonhomogeneous linear systems, Linear system with constant coefficients, linear system with periodic coefficients, Fundamental Matrix.

Higher Order Linear ODE: Higher order linear ODE, fundamental solutions, Wronskian, variation of parameters, Linear differential equations of order n, Linear equations with analytic coefficients.

Boundary Value Problems for Second Order Equations: Ordinary Differential Equations of the Strum Liouville type and their properties, Application to Boundary Value Problems, Eigenvalues and Eigenfunctions, Orthogonality theorem, Expansion theorem. Green's function for Ordinary Differential Equations, Application to Boundary Value Problems

References:

1. Simmons, G.F., Differential Equations, Tata McGraw Hill.
2. Agarwal, R.P., O' Regan, D., An Introduction to Ordinary Differential Equations, Springer, 2000.
3. Codington, E.A., Levinson, N., Theory of Ordinary Differential Equation, McGraw Hill.
4. Ince, E.L., Ordinary Differential Equation, Dover.
5. Piaggio, H.T.H., An Elementary Treatise on Differential Equations and Their Applications, G. BellAnd Sons, Ltd, 1949.
6. Hartman, P., Ordinary Differential Equations, SIAM, 20
7. Hall, G. R., Devaney, R. L., Blanchard, P. (2012). Differential Equations. United States: Cengage Learning.
8. Dan Umbarger, Differential Equations: A Visual Introduction for Beginners.

Rajib Mukherjee

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M. Sc. Course in Mathematics
SEMESTER-I
Course Code: PG-MATH-CC-104

Course title: Topology
Core Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 3:1:0

Topological Spaces and Continuous Functions: Topological spaces, Basis and Subbasis for a topology, Order Topology, Product topology on $X \times Y$, subspace Topology, Interior Points, Limit Points, Derived Set, Boundary of a set, Closed Sets, Closure and Interior of a set, Kuratowski closure operator and the generated topology, Continuous Functions, Open maps, Closed maps and Homeomorphisms, Product Topology, Quotient Topology, Metric Topology, Complete Metric Spaces, Baire-Category Theorem.

Connectedness and Compactness: Connected and Path Connected Spaces, Connected Sets in R, Components and Path Components, Local Connectedness. Compact Spaces, Compact Sets in R, Compactness in Metric Spaces, Totally Bounded Spaces, Ascoli-Arzelà Theorem, The Lebesgue Number Lemma, Local Compactness.

Countability Axioms, The Separation Axioms, Lindelof spaces, Regular spaces, Normal spaces (definition and examples only).

References:

1. Dugundji, J., Topology, Allyn and Bacon, 1966.
2. Simmons, G.F., Introduction to Topology and Modern Analysis, McGraw-Hill, 1963.
3. Kumaresan, S., Topology of Metric Spaces, Narosa Publishing House, 2010.
4. Kelley, J.L., General Topology, Van Nostrand Reinhold Co., New York, 1995.
5. Young, J.G., Topology, Addison-Wesley Reading, 1961.
6. Willard, S., General Topology, Dover.
7. Engelking, R., General Topology, Polish Scientific Pub.
8. Sierpinski, W., Introduction to General Topology, The University of Toronto Press, Canada.
9. Kuratowski, K., General Topology, Vol. I, Academic Press, New York and London.
10. Munkres, J.R., Topology, A First Course, Prentice Hall of India Pvt. Ltd., New Delhi, 2000

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M. Sc. Course in Mathematics
SEMESTER-I
Course Code: MATH-C-105 Course title: Advanced Programming in C
Core Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 2:0:2

Structure of C Programs: C's Character Set, The form of a C Program, The layout of C Programs, Preprocessor Directives, Add Comments to a Program.

Data Types, Operators and Expression: Variables name, Data type and size, Constants, Arithmetic Operators, Relational and logical operators, Type conversions, Increment and decrement operator, bitwise operators, Assignment operators and expressions, Conditional expressions, Precedence and order of Evaluation.

Control Flow: Statements and blocks, if-else, switch, for loops, while loops, do-while loops, break and continue, goto and labels.

Functions: Basics of functions, Functions returning, External variables, Scope Rules, Header files, Static variables, Register variables, Global variables, Recursion.

Arrays and Pointers: Arrays, String, Multi-dimensional arrays, Pointer and addresses, Pointers and function arguments, Address arithmetic, Character pointers and functions, Pointer arrays, Pointers to pointers.

Structures: Basics of structures, Structures and functions, Arrays of structures, Pointers to structures, Typedef, Unions.

Input and Output: Standard input and output, Formatted output, Variable length argument list, Formatted input, File access, Open, read, write, close file.

References:

1. Gottfried, B.S., Programming with C, Schaum's Outlines, Second Edition, Tata McGraw-Hill, 2006.
2. Dromey, R.G., How to Solve it by Computer, Pearson Education, Fourth Reprint, 2007.
3. Kernighan, B.W., Ritchie, D.M, The C Programming language, Second Edition, Pearson Education, 2006.

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DETAILS OF COURSE:

SEMESTER II

Duration: 6 Months (Including Examinations) Total 20 credits (Marks: 250)

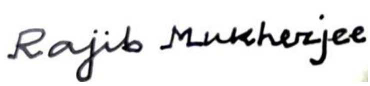
Course/Paper	Topics	Marks		Credit	Hrs/Wk
		SEE	IA		
SEMESTER II					
PG-MATH-CC-201	Algebra-II	40	10	4	4
PG-MATH-CC-202	Classical Mechanics	40	10	4	4
PG-MATH-CC-203	Measure Theory and Integration	40	10	4	4
PG-MATH-CC-204	Operations Research	40	10	4	4
PG-MATH-CC-205	Computer Practical (application of Matlab and typesetting software Latex)	40	10	4	6

M. Sc. Course in Mathematics
SEMESTER-II
Course Code: MATH-C-201
Course title: Algebra-II
Core Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 3:1:0

Group A (25 Marks)

Rings: Ideals and Homomorphisms, Prime and Maximal Ideals, Quotient Field of an Integral Domain, Polynomial and Power Series Rings. Divisibility Theory: Euclidean Domain, Principal Ideal Domain, Unique Factorization Domain, Gauss' Theorem, Eisenstein's criterion

Field: Fields, finite fields, field extensions.



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Group B (25 Marks)

Inner Product Spaces: Inner product spaces. Cauchy-Schwartz inequality. Orthogonal vectors and orthogonal complements. Orthonormal sets and bases. Bessel's inequality. Gram-Schmidt orthogonalization method. Hermitian, Self Adjoint, Unitary, and Orthogonal transformation for complex and real spaces. Bilinear and Quadratic forms, real quadratic forms.

Modules: Modules over commutative rings, examples: vector spaces, commutative rings, Zmodules, F[X]-modules; sub modules. Quotient modules, Homomorphisms, isomorphism theorems.

References:

1. Roman, S., Fundamentals of Group Theory: An Advanced Approach, Birkhauser, 2012.
2. Malik, D.S., Mordesen, J.M., Sen, M.K., Fundamentals of Abstract Algebra, The McGraw-Hill Companies, Inc, 1997.
3. Rotman, J., The Theory of Groups: An Introduction, Allyn and Bacon, Inc., Boston, 1973.
4. Rotman, J., A First Course in Abstract Algebra, Prentice Hall, 2005.
5. Pinter, Charles. C., A Book of Abstract Algebra, McGraw Hill, 1982.
6. Herstein, I.N., Topics in Abstract Algebra, Wiley Eastern Limited, 1975.
7. Gallian, J., Contemporary Abstract Algebra, Narosa, 2011.
8. Jacobson, N., Basic Algebra, I & II, Hindusthan Publishing Corporation, India.
9. Hungerford, T.W., Algebra, Springer.
10. Artin, M., Algebra, Prentice Hall of India, 2007.
11. Goldhaber, J.K., Ehrlich, G., Algebra, The Macmillan Company, Collier-Macmillan Limited, London.
12. Dummit, D.S., Foote, R.M., Abstract Algebra, Second Edition, John Wiley & Sons, Inc., 1999
13. Artin, M., Algebra, Prentice Hall of India, 2007.
14. Halmos, P.R., Finite Dimensional Vector Spaces, Springer, 2013
15. Roman, S., Advanced Linear Algebra, Springer, 2007.
16. Curtis, C.W., Linear Algebra: An Introductory Approach, Springer (SIE), 2009.
17. Hoffman, K., Kunze, R., Linear Algebra, Prentice Hall of India, 1978.
18. Dummit, D.S., Foote, R.M., Abstract Algebra, Second Edition, John Wiley & Sons, Inc., 1999.
19. Apostol, T.M., Calculus Vol. I & II, John Wiley and Sons, 2011.
20. C. Musili : Rings and Modules

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M. Sc. Course in Mathematics SEMESTER-II
Course Code: PG-MATH-CC-202
Course title: Classic Mechanics
Core Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 3:1:0

Generalized coordinates. Virtual work. D'Alemberts principle. Unilateral and bilateral constraints. Holonomic and Non-holonomic systems. Scleronomic and Rheonomic systems. Lagrange's equations of first and second kind. Uniqueness of solution. Energy equation for conservative fields. Euler's dynamical equations. Rotating coordinate system. Motion related to rotating earth. Faucaull's pendulum and torque free motion of a rigid body about a fixed point. Motion of a symmetrical top and theory of small vibrations.

Hamilton's variables. Hamilton canonical equation. Homogeneity of space and time conservation principles, Noethers theorem.Cyclic coordinates. Routh's equations. Hamilton's principle. Principle of least action. Poisson's Bracket. Poisson's identity. Jacobi-Poisson Theorem.

Time dependent Hamilton-Jacobi equation and Jacobi's Theorem. Lagrange Brackets. Condition of canonical character of transformation in terms of Lagrange brackets and Poisson brackets. Invariance of Lagrange brackets and Poisson brackets under canonical transformations.

References:

1. H. Goldstein: Classical Mechanics.
2. N.C. Rana and P.S. Jog: Classical Mechanics.
3. Louis N. Hand and Janet D. Finch: Analytical Mechanics.
4. A.S. Ramsay: Dynamics Part – II.
5. S.L. Loney: Rigid Dynamics.

M. Sc. Course in Mathematics SEMESTER-II
Course Code: MATH-CC-203
Course title: Measure Theory and Integration
Core Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 3:1:0

Bounded Variation: Functions of Bounded Variation and their properties, Riemann Stieltjes integrals and its properties, Absolutely Continuous Functions.

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The Lebesgue Measure: Lebesgue Measure: (Lebesgue) Outer measure and measure on R, Measurable sets form an σ-algebra, Borel sets, Borel σ-algebra, open sets, closed sets are measurable, Existence of a non-measurable set, Measure space, Measurable Function and its properties, Borel measurable functions, Concept of Almost Everywhere (a.e.), sets of measure zero, Steinhaus Theorem (Statement only), Sequence of measurable functions, Egorov's Theorem, Applications of Lusin Theorem.

The Lebesgue Integral: Simple and Step Functions, Lebesgue integral of simple and step functions, Lebesgue integral of a bounded function over a set of finite measure, Bounded Convergence Theorem, Lebesgue integral of non-negative function, Fatou's Lemma, Monotone Convergence Theorem. The General Lebesgue integral: Lebesgue Integral of an arbitrary Measurable Function, Lebesgue Integrable functions. Dominated Convergence Theorem. L^pSpaces.

Riemann Integral as Lebesgue Integral. Product measure spaces, Fubini's Theorem (applications only)

Reference:

1. Halmos, P.R., Measure Theory, Springer, 2007.
2. Rudin, W., Principles of Mathematical Analysis, Tata McGraw Hill, 2001.
3. Rudin, W., Real and Complex Analysis, McGraw-Hill Book Co., 1966.
4. Tao, T., An Introduction to Measure Theory, American Mathematical Society, 2011.
5. Kolmogorov, A.N., Fomin, S.V., Measures, Lebesgue Integrals, and Hilbert Space, Academic Press, New York & London, 1961.
6. Apostol, T.M., Mathematical Analysis, Narosa Publishing House, 2002 7. Barra, G.D., Measure Theory and Integration, Woodhead Pub, 1981.
8. Kingman, J.F.C., Taylor, S.J., Introduction to Measure and Probability, Cambridge University Press, 1966.
9. Cohn, D.L., Measure Theory, Birkhauser, 2013.
10. Wheeden, R.L., Zygmund, A., Measure and Integral, Monographs and Textbooks in Pure and Applied Mathematics, 1977.
11. Royden, H.L., Real Analysis, 3rd Edition, Macmillan, New York & London, 1988

M. Sc. Course in Mathematics SEMESTER-II
Course Code: PG-MATH-CC-204
Course title: Operations Research
Core Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 3:1:0

Rajib Mukherjee

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Queuing Theory: Basic Structures of queuing models, Measuring system performance, Monrovian property of exponential distribution, Stochastic process and Markov Chain, Steady state Birth Death Process, Little's Law (Statement and its applications only), Steady state solution for the M/M/1 model, Method for solving steady-state difference equation, Queues with parallel channels (M/M/C) , Queues with parallel channels and Truncation (M/M/c/K), Erlang's Formula (M/M/c/c), Queues with unlimited service, Non-Poisson queue -M/G/1.

Reliability: Concept, Reliability Definition, Mean Time to Failure, Hazard Rate Function, Conditional Reliability, System Reliability, Constant Failure Rate Models, Time dependent failure models, System Failure rate, Reliability of the Systems connected in Series or / and parallel, Combined Series Parallel System, Reliability of k-out of 'm' System.

Inventory Control: Inventory control -Deterministic including price breaks and Multi-item with constraints, Probabilistic (with and without lead time): News Vendor Model, Continuous review inventory model.

References:

1. Ronald, V. Hartley, Operations Research, A Managerial Emphasis Goodyear Publishing Company Inc., 1976.
2. Beveridge and Scheehter, Optimization Theory and Practice, McGraw Hill Kogakusha, Tokyo, 1970.
3. Gross and Harris, Queueing Theory, John Wiley
4. Johnson L.A., Montgomery, Operations Research in Production Planning, Scheduling & Inventory Control, John Wiley, 1974.

M. Sc. Course in Mathematics SEMESTER-II
Course Code: PG-MATH-CC-205
Course title: Computer Practical (application of Matlab and typesetting software Latex)
Core Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 2:0:2

MATLAB: Group A (25 Marks)

Working with matrix: Generating matrix, Concatenation, Deleting rows and columns. Symmetric matrix, matrix multiplication, Test the matrix for singularity, magic matrix. Matrix analysis using function: norm, normest, rank, det, trace, null, orth ,rref, subspace, inv, expm, logm, sqrtm, funm.

Rajib Mukherjee

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Array: Addition, Subtraction, Element-by-element multiplication, Element-byelement division, Element by-element left division, Element-by-element power. Multidimensional Arrays.

Graph Plotting: Plotting Process, Creating a Graph, Graph Components, Figure Tools, Arranging Graphs Within a Figure, Choosing a Type of Graph to Plot, Editing Plots, Plotting Two Variables with Plotting Tools

LATEX: Group B (25 Marks)

Getting Started: Introduction, Installation of the software LaTeX, Installing Extra Packages, Basics, Understanding Latex compilation.

Common Elements: Basic Syntax, Fonts, color, Special Characters, Writing equations, Matrix, Tables.

Page Layout: Titles, Abstract, Chapters, Sections, Nomenclature, Customizing Page Headers and Footers, References, Equation references, citation. List making environments, Table of contents, generating new commands, Figure handling numbering, List of figures, List of tables, generating index, Importing Graphics, Floats, Figures and Captions, Footnotes and Margin Notes.

Packages: Geometry, Hyperref, amsmath, amssymb, algorithms, algorithmic graphic, color, tilez listing, etc.

Classes: Article, book, thesis, report, beamer, slides. IEEtran.

Applications: Writing Resume, Writing question paper, Writing articles/ research papers, Presentation using beamer.

Theory, Practical and exercises based on the above concepts.

References:

1. Kottwitz, S., LaTeX Beginner's Guide, Packt Publishing, 2011.
2. Kopka, H., Daly, P.W., Guide to LaTeX, Addison-Wesley Professional; 4th edition, 2003.
3. Grätzer, G., More Math Into LaTeX, Springer, Revised 5th edition, 2016.
4. Pratap, Rudra etting Started with MATLAB 5-A Quick Introduction for Scientists and Engineers, 1998

Rajib Mukherjee

Signature of Coordinator
Department of Mathematics
Murshidabad University

Choice Based Credit System (CBCS)

MURSHIDABAD UNIVERSITY

DEPARTMENT OF MATHEMATICS

POSTGRADUATE PROGRAMME

M. SC. COURSE IN MATHEMATICS

(Four Semesters)

(Courses effective from Academic Year 2022-23)

SYLLABUS OF COURSES TO BE OFFERED

M. Sc. Course in Mathematics

(Pure and Applied Streams)

Total Marks: 1000

(Total four semester course carrying 250 marks in each semester)

Outline of the Choice Based Credit Semester System

Transaction Categories: CC: Core Course; **CB**: Choice Based Course; **E**: Elective Paper; **ME:** Minor Elective, **PW**: Project Work

Evaluation Categories: SEE: Semester End Examination; **IA**: Internal Assessment

Course/Paper	Topics		Marks		Credit	Hrs/Wk
			SEE	IA		
SEMESTER III						
PG-MATH-CC-301	Functional Analysis		40	10	4	4
PG-MATH-CC-302	Integral Equations and Calculus of Variations		40	10	4	4
PG-MATH-ME-301 **(Minor Elective)**	Mathematical Methods		40	10	4	4
Discipline Specific Elective Elective-I and Elective-II (Choose any two Elective Paper from PG-MATH-E-301 to PG-MATH-E-306)	PG-MATH-E-301	Advanced Complex Analysis-I	40	10	4	4
	PG-MATH-E-302	Advanced Number Theory- I				
	PG-MATH-E-303	Graph Theory and Algorithm-I				
	PG-MATH-E-304	Mathematical Biology-I				
	PG-MATH-E-305	Differential Geometry-I				
	PG-MATH-E-306	Fluid Mechanics-I				

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M. Sc. Course in Mathematics
(Pure and Applied Streams)
Total Marks: 1000
(Total four semester course carrying 250 marks in each semester)

Outline of the Choice Based Credit Semester System

Transaction Categories: CC: Core Course **CB**: Choice Based Course; **E**: Elective Paper; PW: Project Work
Evaluation Categories: SEE: Semester End Examination; **IA**: Internal Assessment

<table>
<tr><th rowspan="2">Course/Paper</th><th rowspan="2" colspan="2">Topics</th><th colspan="2">Marks</th><th rowspan="2">Credit</th><th rowspan="2">Hrs/Wk</th></tr>
<tr><th>SEE</th><th>IA</th></tr>
<tr><td colspan="7">SEMESTER IV</td></tr>
<tr><td>PG-MATH-CC-401</td><td colspan="2">Fuzzy Set Theory and Optimization</td><td>40</td><td>10</td><td>4</td><td>4</td></tr>
<tr><td>PG-MATH-CC-402</td><td colspan="2">Numerical Analysis and Partial Differential Equation</td><td>40</td><td>10</td><td>4</td><td>4</td></tr>
<tr><td>PG-MATH-PW-403</td><td colspan="2">Project Work</td><td>40</td><td>10</td><td>4</td><td>4</td></tr>
<tr><td rowspan="6">Discipline Specific Elective

Elective-III and Elective-IV

(Any two from PG-MATH-E-401 to PG-MATH-E-406)</td><td>PG-MATH-E-401</td><td>Advanced Complex Analysis-II</td><td rowspan="6">40</td><td rowspan="6">10</td><td rowspan="6">4</td><td rowspan="6">4</td></tr>
<tr><td>PG-MATH-E-402</td><td>Advanced Number Theory-II</td></tr>
<tr><td>PG-MATH-E-403</td><td>Graph Theory and Algorithm-II</td></tr>
<tr><td>PG-MATH-E-404</td><td>Mathematical Biology-II</td></tr>
<tr><td>PG-MATH-E-405</td><td>Differential Geometry-II</td></tr>
<tr><td>PG-MATH-E-406</td><td>Fluid Mechanics-II</td></tr>
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DETAILS OF COURSE:

SEMESTER III

Duration: 6 Months (Including Examinations) Total 20 credits (Marks: 250)

<table>
<tr><th rowspan="2">Course/Paper</th><th rowspan="2" colspan="2">Topics</th><th colspan="2">Marks</th><th rowspan="2">Credit</th><th rowspan="2">Hrs/Wk</th></tr>
<tr><th>SEE</th><th>IA</th></tr>
<tr><td colspan="7">SEMESTER III</td></tr>
<tr><td>PG-MATH-CC-301</td><td colspan="2">Functional Analysis</td><td>40</td><td>10</td><td>4</td><td>4</td></tr>
<tr><td>PG-MATH-CC-302</td><td colspan="2">Integral Equations and Calculus of Variations</td><td>40</td><td>10</td><td>4</td><td>4</td></tr>
<tr><td>PG-MATH-ME-301</td><td colspan="2">Mathematical Methods</td><td>40</td><td>10</td><td>4</td><td>4</td></tr>
<tr><td rowspan="6">Discipline Specific Elective

Elective-I and Elective-II

(Choose any two Elective Paper from PG-MATH-E-301 to PG-MATH-E-306)</td><td>PG-MATH-E-301</td><td>Advanced Complex Analysis-I</td><td rowspan="6">40</td><td rowspan="6">10</td><td rowspan="6">4</td><td rowspan="6">4</td></tr>
<tr><td>PG-MATH-E-302</td><td>Advanced Number Theory- I</td></tr>
<tr><td>PG-MATH-E-303</td><td>Graph Theory and Algorithm-I</td></tr>
<tr><td>PG-MATH-E-304</td><td>Mathematical Biology-I</td></tr>
<tr><td>PG-MATH-E-305</td><td>Differential Geometry-I</td></tr>
<tr><td>PG-MATH-E-306</td><td>Fluid Mechanics-I</td></tr>
</table>

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M. Sc. Course in Mathematics
SEMESTER-III
Course Code: PG-MATH-CC-301
Course title: Functional Analysis
Core Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 3:1:0

Banach Spaces: Normed Linear Spaces, Banach Spaces, Equivalent Norms, Finite dimensional normed linear spaces and local compactness, Quotient Space of normed linear spaces and its completeness, Riesz Lemma, Fixed Point Theorems (Banach, Kannan's) and its applications. Bounded Linear Transformations, Normed linear spaces of bounded linear transformations, Uniform Boundedness
Theorem, Principle of Condensation of Singularities, Open Mapping Theorem, Closed Graph Theorem, Linear Functionals, Hahn-Banach Theorem, Dual Space, Reflexivity of Banach Spaces.

Hilbert Spaces: Real Inner Product Spaces and its Complexification, Cauchy-Schwarz Inequality, Parallelogram law, Pythagorean Theorem, Bessel's Inequality, Gram-Schmidt Orthogonalization Process, Hilbert Spaces, Orthonormal Sets, Complete Orthonormal Sets and Parseval's Identity, Structure of Hilbert Spaces, Orthogonal Complement and Projection Theorem. Riesz Representation Theorem, Adjoint of an Operator on a Hilbert Space, Reflexivity of Hilbert Spaces, Self-adjoint Operators, Positive Operators, Projection Operators, Normal Operators, Unitary Operators.

References:

1. Brown, A., Pearcy, C., Introduction to Operator Theory I: Elements of Functional Analysis, Springer-Verlag New York, 1977.
2. Suhubi, E.S., Functional Analysis, Springer, New Delhi, 2009.
3. Aliprantis, C.D., Burkinshaw, O., Principles of Real Analysis, 3rd Edition, Harcourt Asia Pte Ltd., 1998.
4. Ponnusamy, S., Foundations of Functional Analysis, Narosa, 2011.
5. Goffman, C., Pedrick, G., First Course in Functional Analysis, Prentice Hall of India, New Delhi, 1987.
6. Bachman, G., Narici, L., Functional Analysis, Academic Press, 1966.
7. Taylor, A.E., Introduction to Functional Analysis, John Wiley and Sons, New York, 1958.
8. Simmons, G.F., Introduction to Topology and Modern Analysis, McGraw-Hill, 1963.
9. Conway, J.B., A Course in Functional Analysis, Springer Verlag, New York, 1990.
10. Rudin, W., Functional Analysis, Tata McGraw Hill, 1992.
11. Limaye, B.V., Functional Analysis, Wiley Eastern Ltd, 1981.
12. Kreyszig, E., Introductory Functional Analysis and its Applications, John Wiley and Sons, New York, 1978

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M. Sc. Course in Mathematics
SEMESTER-III
Course Code: PG-MATH-CC-302
Course title: Integral Equations and Calculus of Variations
Core Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 3:1:0

Integral Equations: Basic concepts, Volterra integral equations, relationship between linear differential equations and Volterra equations, resolvent kernel, method of successive approximations, convolution type equations, Volterra equation of the first kind. Abel's integral equation. Fredholm integral equations, Fredholm equations of the second kind, the method of Fredholm determinants, iterated kernels, integral equations with degenerate kernels, eigen values and eigen functions of a Fredholm alternative, construction of Greens function for BVP, singular integral equations.

Calculus of Variations: Euler–Lagrange equations, degenerate Euler equations, Natural boundary conditions, transversality conditions, simple applications of variational principle, sufficient conditions for extremum. Variational formulation of BVP, minimum of quadratic functional.
Approximate methods – Galerkin's method, weighted-residual methods, Collocation methods.
Variational methods for time dependent problems.

References:

1. Lovitt, W.V., Linear Integral Equations, Dover.
2. Tricomi, F.G., Integral Equations, Dover
3. Israel Gelfand, Calculus of variations, Dover
4. Jost, J, Jürgen J, and Xianqing L-J. *Calculus of variations*, Cambridge University Press, 1998.

M. Sc. Course in Mathematics
SEMESTER-III
Course Code: PG-MATH-ME-301
Course title: Mathematical Methods
Core Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 0:0:4

Vector algebra and vector calculus. Linear algebra, matrices, Cayley-Hamilton Theorem. Eigenvalues and eigenvectors. Linear ordinary differential equations of first & second order,

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Special functions (Hermite, Bessel, Laguerre and Legendre functions). Fourier series, Fourier and Laplace transforms. Elements of complex analysis, analytic functions; Taylor & Laurent series; poles, residues and evaluation of integrals. Elementary probability theory, random variables, binomial, Poisson and normal distributions. Central limit theorem.

Elective Papers :

<table>
<tr><th rowspan="2">Course/Paper</th><th rowspan="2" colspan="2">Topics</th><th colspan="2">Marks</th><th rowspan="2">Credit</th><th rowspan="2">Hrs/Wk</th></tr>
<tr><th>SEE</th><th>IA</th></tr>
<tr><td colspan="7">SEMESTER III</td></tr>
<tr><td rowspan="6">Discipline Specific Elective

Elective-I and Elective-II

(Choose any two Elective Paper from PG-MATH-E-301 to PG-MATH-E-306)</td><td>PG-MATH-E-301</td><td>Advanced Complex Analysis-I</td><td rowspan="6">40</td><td rowspan="6">10</td><td rowspan="6">4</td><td rowspan="6">4</td></tr>
<tr><td>PG-MATH-E-302</td><td>Advanced Number Theory- I</td></tr>
<tr><td>PG-MATH-E-303</td><td>Graph Theory and Algorithm-I</td></tr>
<tr><td>PG-MATH-E-304</td><td>Mathematical Biology-I</td></tr>
<tr><td>PG-MATH-E-305</td><td>Differential Geometry-I</td></tr>
<tr><td>PG-MATH-E-306</td><td>Fluid Mechanics-I</td></tr>
</table>

M. Sc. Course in Mathematics
SEMESTER-III
Course Code: PG-MATH-E-301
Course title: Advanced Complex Analysis I
Elective Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 3:1:0

Harmonic functions, Characterisation of Harmonic functions by mean-value property. Poisson's integral formula. Dirichlet problem for a disc. Doubly periodic functions. Weierstrass Elliptic function, Weierstrass σ-function and their properties.

Entire functions, M(r, f) and its properties (statements only). Meromorphic functions. Expansions. Definition of the functions m (r, a), N(r, a) and T(r). Nevanlinna's first fundamental theorem. Cartan's identity and convexity theorems. Orders of growth. Order of a meromorphic function. Comparative growth of logM(r) and T(r).

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References:

1. E. T. Copson: An Introduction to the Theory of Functions of a Complex Variable.
2. E. C. Titthmarsh: The Theory of Functions.
3. A. I. Markushevich: Theory of Functions of a Complex Variable (Vol. I, II &III).
4. L. V. Ahlfors: Complex Analysis.
5. J. B. Conway: Functions of One Complex Variable.
6. A. I. Markushevich: The Theory of Analytic Functions, A Brief Course.
7. C. Caratheodory: Theory of Functions of a Complex Variable.
8. A. S. B. Holland: Introduction to the Theory of Entire functions.
9. W. K. Hayman: Meromorphic Functions.

SEMESTER-III
Course Code: PG-MATH-E-302
Course title: Advanced Number Theory I
Elective Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 3:1:0

Linear Diophantine equation, prime counting function, statement of prime number theorem.

Goldbach conjecture, linear congruences, complete set of residues.

Chinese remainder theorem, Fermat's little theorem, Wilson's theorem, Statement of Fermat's Last theorem and their applications.

Number theoretic functions, sum and number of divisors, totally multiplicative functions, definition and properties of the Dirichlet product, the Mobius Inversion formula, the greatest integer function.

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Euler's phi-function, Euler's theorem, reduced set of residues, some properties of Euler's phifunction.

References:

1. David M. Burton, Elementary Number Theory, Tata McGraw-Hill. 2. Neville Robbins, Beginning Number Theory, Narosa Publishing House Pvt. Ltd.

M. Sc. Course in Mathematics
SEMESTER-III
Course Code: PG-MATH-E-303
Course title: Graph Theory and Algorithm-I
Elective Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 3:1:0

Fundamental Concepts: Basic Definitions. Graphs, Vertex degrees, Walks, Paths, Trails, Cycles, Circuits, Subgraphs, Induced sub-graph, Cliques, Components, Adjacency Matrices, Incidence Matrices, Isomorphism.

Graphs with Special Properties: Complete Graphs. Bipartite Graphs. Connected Graphs, kconnected Graphs, Edge-connectivity, Cut-vertices, Cut-edges. Eulerian Trails, Eulerian Circuits, Eulerian Graphs: characterization, Hamiltonian (Spanning) Cycles, Hamiltonian Graphs: Necessary condition, Sufficient conditions (Dirac, Ore, Chvatal, Chvatal-Erdos), Hamiltonian Closure, Traveling Salesman Problem.

Trees: Basic properties, distance, diameter. Rooted trees, Binary trees, Binary Search Trees. Cayley's Formula for counting number of trees. Spanning trees of a connected graph, Depth first search (DFS) and Breadth first search (BFS) Algorithms, Minimal spanning tree, Shortest path problem, Kruskal's Algorithm, Prims Algorithm, Dijkstras Algorithm. Chinese Postman Problem.

Coloring of Graphs: Vertex coloring: proper coloring, k-colorable graphs, chromatic number, upper bounds, Cartesian product of graphs, Structure of k-chromatic graphs, Mycielskis Construction, Colorcritical graphs, Chromatic Polynomial, Clique number, Independent (Stable) set of vertices, Independence number, Clique covering, Clique covering number.

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Perfect Graphs: Chordal graphs, Interval graphs, Transitive Orientation, Comparability Graphs. Edge-coloring, Edge-chromatic number, Line Graphs.

References:

1. West, D.B., Introduction to Graph Theory, Prentice-Hall of India Pvt. Ltd., New Delhi 2003.
2. Harary, F., Graph Theory, Addison-Wesley, 1969.
3. Parthasarathi, K.R., Basic Graph Theory, Tata McGraw-Hill Publ. Co. Ltd., New Delhi, 1994.
4. Foulds, L.R., Graph Theory Applications, Narosa Publishing House, New Delhi, 1993.
5. Bondy, J.A., Murty, U.S.R., Graph Theory with Applications, Elsevier science, 1976.
6. Chartrand, G., Lesniak, L., Graphs and Digraphs, Chapman & Hall, 1996.
7. Ore, O., Theory of Graphs, AMS Colloq. 38, Amer.Math.Soc., 1962.

M. Sc. Course in Mathematics
SEMESTER-III
Course Code: PG-MATH-E-304
Course title: Mathematical Biology-I
Elective Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 3:1:0

Mathematical biology and the 27arbour27r process: an overview. Continuous models: Malthus model, logistic growth, Allee effect, Gompertz growth, Michaelis-Menten Kinetics, Holling type growth, bacterial growth in a chemostat, harvesting a single natural population, Prey predator systems and LotkaVolterra equations, populations in competitions, epidemic models (SI, SIR, SIRS, SIC)

Activator-inhibitor system, insect outbreak model: Spruce Budworm. Numerical solution of the models and its graphical representation. Qualitative analysis of continuous models: Steady state solutions, stability and linearization, multiple species communities and Routh-Hurwitz Criteria. Phase plane methods and qualitative solutions, bifurcations and limit cycles with examples in the context of biological scenario. Spatial models: One species model with diffusion. Two species model with diffusion, conditions for diffusive instability, spreading colonies of microorganisms, Blood flow in circulatory system, travelling wave solutions, spread of genes in a population.

Discrete models: Overview of difference equations, steady state solution and linear stability analysis. Introduction to discrete models, linear models, growth models, decay models, drug delivery problem, discrete prey predator models, density dependent growth models with harvesting, host-parasitoid systems (Nicholson-Baileymodel), numerical solution of the models and its graphical representation. Case studies. Optimal exploitation models, models in genetics, stage structure models, age structure models.

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M. Sc. Course in Mathematics
SEMESTER-III
Course Code: PG-MATH-E-305
Course title: Differential Geometry I
Elective Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 3:1:0

Calculus on Euclidean Spaces: Euclidean Spaces, Tangent Vectors, Directional Derivatives, Curves in R^3, 1-forms, Differential Forms, Mappings.

Frame Fields: Dot Product, Curves, Frenet Formulae, Arbitrary Speed Curves, Covariant Derivatives, Frame Fields, Connection Forms, The Structural Equations.

Euclidean Geometry: Isometries of R^3, Tangent Map of an Isometry, Orientation, Euclidean Geometry, Congruence of Curves.

Calculus on a Surface: Surfaces in R^3, Patch Computations, Differentiable Functions and Tangent Vectors, Differentiable Forms on a Surface, Mappings of Surfaces, Integration of Forms, Topological Properties of Surfaces, Manifolds.

References: 1. O'Neill, Barret, Elementary Differential Geometry, Elsevier Academic Press, 2006.

2. Pressley, A., Elementary Differential Geometry, Springer, 2004

M. Sc. Course in Mathematics
SEMESTER-III
Course Code: MATH-E-306
Course title: Fluid Mechanics-I
Elective Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 3:1:0

Incompressible Fluid: Equations of continuity for incompressible fluid, Examples, Eulerian and Lagrangian equation of motion. Bernoulli's equation for incompressible fluid, Rotational and irrotational motion, Velocity potential, Stream function, Stream line, Path line, Complex potential, Complex velocity, Source, Sink, Doublets and their images circle theorem, Euler's momentum theorem and D'Alembert paradox.

Inviscid Compressible Fluid: Field equations, Circulation, Propagation of small disturbance. Mach number and cone, Bernoulli's equation. Irrotational motion, Velocity potential. Bernoulli's equation in terms of Mach number. Pressure, density, temperature in terms of Mach number, Critical conditions. Steady channel flow, Area-velocity relation. Mass flow through a converging nozzle. Flow through a de-Laval nozzle. Normal shock waves, Governing equations and the solution. Entropy change.

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Vortex Motion: Vortex line, Vortex tube, Properties of the vortex, Strength of the vortex, Rectilinear vortices, Velocity component, center of vortices. A case of two vortex filaments, vortex pair. Vortex doublet. Image of vortex filament with respect to a plane. An infinite single row of parallel rectilinear vortices of same strength. Two infinite row of parallel rectilinear vortices, Karman's vortex street. Rectilinear vortex with circular section. Rankine's combine vortex. Rectilinear vortices with elliptic section.

References:

1. Prandt, L., Essential of fluid dynamics, Springer, 2004.
2. White, F.M., Viscous Fluid Flow, McGraw Hill, 1991.
3. Panton, R.L., Incompressible Flow, John Wiley and Sons, 1984.

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DETAILS OF COURSE:

SEMESTER IV

Duration: 6 Months (Including Examinations) Total 20 credits (Marks: 250)

<table>
<tr><th rowspan="2">Course/Paper</th><th rowspan="2" colspan="2">Topics</th><th colspan="2">Marks</th><th rowspan="2">Credit</th><th rowspan="2">Hrs/Wk</th></tr>
<tr><th>SEE</th><th>IA</th></tr>
<tr><td colspan="7">SEMESTER IV</td></tr>
<tr><td>PG-MATH-CC-401</td><td colspan="2">Fuzzy Set Theory and Optimization</td><td>40</td><td>10</td><td>4</td><td>4</td></tr>
<tr><td>PG-MATH-CC-402</td><td colspan="2">Numerical Analysis and Partial Differential Equation</td><td>40</td><td>10</td><td>4</td><td>4</td></tr>
<tr><td>PG-MATH-PW-403</td><td colspan="2">Project Work</td><td>40</td><td>10</td><td>4</td><td>4</td></tr>
<tr><td rowspan="6">Discipline Specific Elective

Elective-III and Elective-IV

(Any two from PG-MATH-E-401 to PG-MATH-E-406)</td><td>PG-MATH-E-401</td><td>Advanced Complex Analysis-II</td><td rowspan="6">40</td><td rowspan="6">10</td><td rowspan="6">4</td><td rowspan="6">4</td></tr>
<tr><td>PG-MATH-E-402</td><td>Advanced Number Theory-II</td></tr>
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M. Sc. Course in Mathematics
SEMESTER-IV
Course Code: PG-MATH-CC-401
Course title: Fuzzy Set Theory and Optimization
Core Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 3:1:0

Fuzzy Sets and its Operations: Definition of Fuzzy sets. Alpha-set. Normality Extension Principle. Basic Operations like inclusion. Completion, Union and intersection, Difference. Fuzzy numbers. Addition, Subtraction, Multiplication and Division, Triangular and trapezoid fuzzy numbers. equilibrium, dual point, characterization theorem of fuzzy complements, increasing and decreasing generators. t-norms, tconorms, their axioms and corresponding characterization theorems, dual triple.

Fuzzy Relations: Fuzzy equivalence relations, fuzzy Compatibility relations, fuzzy ordering relations,

Fuzzy Arithmetic: Linguistic variables, arithmetic operations on fuzzy numbers (On, in general)

Defuzzification of Fuzzy Numbers: Definition, Different types of defuzzification techniques.

Fuzzy Logic: A brief review of Classical logic, fuzzy propositions, fuzzy quantifiers, fuzzy inference rules, inferences from fuzzy propositions.

Fuzzy Decision Making: Linear Programming Problems with fuzzy resources

Classical Optimization: Unconstrained and equality-constrained extremum. First order and second order necessary conditions. Sufficient conditions. Working principle for testing optimality.

Optimality with equality constraints only and with both equality and inequality constraints. Farkas lemma (Forms I and II). Theorem of the alternative (Forms I and II). Fritz-John necessary conditions. Kuhn-Tucker first and second order necessary conditions. Sufficient condition. Working procedure for testing optimality. Saddle point of the Lagrangian and its relation to optimality.

Duality in non-linear programming, Weak duality theorem, Wolfe's duality theorem, Duality for quadratic programming

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References:

1. The Importance of Being Fuzzy – A. Sangalli.
2. Fuzzy Sets and Fuzzy Logic *Theory and Applications* – G. J. Klir and B. Yuan.
3. Introduction to Fuzzy Arithmetic *Theory and Applications* – A. Kaufmann and M. M. Gupta.
4. Fuzzy Sets and Systems – D. Dubois and H. Prade.
5. Fuzzy Set Theory – R. Lowen.
6. A First Course in Fuzzy Logic – H. T. Nguyen and E. A. Walker.
7. Fuzzy Logic – J. E. Baldwin.
8. Fuzzy Set Theory and Its Applications – H. J. Zimmermann.
9. Fuzzy Multiple Objective Decision Making – Y. J. Lai and C. L. Hwang.
10. Fuzzy Set, Fuzzy Logic, Applications – G. Bojadziev, M. Bojadziev.
11. Fuzzy Control – S. S. Farinwata, D. Filev, and R. Langari.
12. Fuzzy Logic for Planning and Decision Making – F. A. Lootsma
13. Avriel, M., Nonlinear Programming: Analysis and Methods, Dover Publications, 2003

14. Mangasarian, O.L., Nonlinear Programming, Society for Industrial and Applied Mathematics, 1987.
15. Bellman, R., Kalaba, R., Dynamic Programming and Modern Control Theory, Academic Press, 1966.
16. Luenberger, David G and Ye, Yinyu and others, Linear and nonlinear programming, Springer, 1986
17. Bazaraa, Mokhtar S., Hanif D. Sherali, and Chitharanjan M. Shetty. *Nonlinear programming: theory and algorithms*. John Wiley & Sons, 2013.
18. Boyd, Stephen, Stephen P. Boyd, and Lieven Vandenberghe. *Convex optimization*. Cambridge university press, 2004.

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M. Sc. Course in Mathematics
SEMESTER-IV
Course Code: PG-MATH-CC-402
Course title: Numerical Analysis and Partial Differential Equation
Core Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 3:1:0

Numerical **Analysis:**
Review of the basic concept of Numerical solutions of algebraic equations.

Method of iteration and Newton-Raphson method, Rate of convergence, Solution of systems of linear algebraic equations using Gauss elimination and Gauss-Seidel methods, Finite differences, Lagrange, Hermite and spline interpolation, Numerical differentiation and integration, Numerical solutions of ODEs using Picard, Euler, modified Euler and Runge-Kutta methods.

Convergence and stability of Fourth order Runge-Kutta method, multi-step predictor-corrector methods (Adams-Bashforth and Adams-Moulton methods),

Matrices and Linear System of Equations: LU decomposition method for solving systems of equations, Symmetric positive definite matrices and least square approximation, iterative algorithms for linear equations.

Partial Differential Equation:
Introduction and pre-requisite, Genesis and types of solutions of Partial Differential Equations, First order Partial Differential Equations, Classifications of First Order Partial Differential Equations, Charpit's Method for the solution of First Order non-linear Partial Differential Equation.

Linear Partial Differential Equations of second and higher order, Linear Partial Differential Equation with constant coefficient, Solution of homogeneous irreducible Partial Differential Equations, Method of separation of variables, Particular integral for irreducible non-homogeneous equations, Linear Partial Differentiable equation with variable coefficients, Canonical forms, Classification of Second order Partial Differential Equations, Canonical transformation of linear Second order Partial Differential equations,

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References:

1. Simmons, G.F., Differential Equations, Tata McGraw Hill.
2. Agarwal, R.P., O' Regan, D., An Introduction to Ordinary Differential Equations, Springer, 2000.
3. Codington, E.A., Levinson, N., Theory of Ordinary Differential Equation, McGraw Hill.
4. Ince, E.L., Ordinary Differential Equation, Dover.
5. Estham, M.S.P., Theory of Ordinary Differential Equations, Van Nostrand Reinhold Compa.Ny, 1970.
6. Piaggio, H.T.H., An Elementary Treatise on Differential Equations and Their Applications, G.

BellAnd Sons, Ltd, 1949.

7. Hartman, P., Ordinary Differential Equations, SIAM, 2002
8. Jain, M.K., Iyenger, S.R.K., Jain, R.K., Numerical Methods for Scientific and Engineering Computation, New Age International
9. Berzin, I.S., Zhidnov, N.P., Computing methods, Elsevier, 1965.
10. Bradie, B., A Friendly Introduction to Numerical Analysis, Pearson Education, India, 2007
11. I. N. Sneddon**:** Elements of Partial Differential Equations.
12. E. Epstein**:** Partial Differential Equations
13. G. Greenspan**:** Introduction to Partial Differential Equations.
14. M. G. Smith**:** Introduction to the Theory of Partial Differential Equations

M. Sc. Course in Mathematics
SEMESTER-IV
Course Code: PG-MATH-PW-403
Course title: Project Work
Core Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 0:0:4

Each student has to undergo through a Project Work under the guidance of the teacher(s) of the Department, and on the basis of subject interest of the students in advanced field of study in different areas of Mathematics

- Project Work has to be made by the students under the guidance of the teacher(s) of the Department, and on the basis of subject interest of the students in advanced field of study in different areas of Mathematics.

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- Dissertation of the Project Work has to be prepared by individual student and the same be submitted to the HOD after countersigned by the concerned teacher(s) and prior to commencement of Viva Voce.

- Project Work related Record has to be maintained by the Department.

- Seminar presentation and Viva-Voce Examination be conducted by the Department.

Elective Papers

Course/Paper	opics		Marks		Credit	Hrs/Wk
			SEE	IA		
SEMESTER IV						
Discipline Specific Elective Elective-III and Elective-IV (Any two from PG-MATH-E-401 to PG-MATH-E-406)	PG-MATH-E-401	Advanced Complex Analysis-II	40	10	4	4
	PG-MATH-E-402	Advanced Number Theory-II				
	PG-MATH-E-403	Graph Theory and Algorithm-II				
	PG-MATH-E-404	Mathematical Biology-II				
	PG-MATH-E-405	Differential Geometry-II				
	PG-MATH-E-406	Fluid Mechanics-II				

SEMESTER-IV
Course Code: |PG-MATH-E-401
Course title: Advanced Complex Analysis II
Elective Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 3:1:0

Nevanlinna's second fundamental theorem. Estimation of S(r) (Statement only). Nevanlinna's theorem on deficient functions. Nevanlinna's five-point uniqueness theorem. Milloux theorem. Milloux basic result. Idea of fix points.

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Functions of several complex variables. Power series in several complex variables. Region of convergence of power series. Associated radii of convergence. Analytic functions. Cauchy-Riemann equations. Cauchy's integral formula. Taylor's expansion. Cauchy's inequalities. Zeros and Singularities of analytic functions. Maximum modulus theorem. Weierstrass preparation theorem (statement only).

References:

1. E. C. Tittmarsh, The Theory of Functions.
2. E. T. Copson, An Introduction to the Theory of Functions of a Complex Variable.
3. A. I. Markushevich, Theory of Functions of a Complex Variable, (Vol. I, II, III).
4. W. Kaplan, An Introduction to Analytic Functions.
5. H. Cartan, Theory of Analytic Functions.
6. R. C. Gunning and H. Rossi, Analytic Functions of Several Complex Variables.
7. B. A. Fuks. An Introduction to the Theory of Analytic Functions of Several Complex Variables.
8. Bochner and Martin. Several Complex Variables.
9. W. K. Hayman: Meromorphic Functions.
10. P. Lelong, L. Gruman: Entire Functions of Several Complex Variables.

M. Sc. Course in Mathematics
SEMESTER-IV
Course Code: PG-MATH-E-402
Course title: Advanced Number Theory II
Elective Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 3:1:0

Order of an integer modulo n, primitive roots for primes, composite numbers having primitive roots.

Euler's criterion, the Legendre symbol and its properties, quadratic reciprocity, quadratic congruences with composite moduli.

Prime number and its properties.

The arithmetic of a prime, pseudo prime and Carmichael Numbers, Fermat Numbers, perfect numbers, Mersenne numbers.

Public key encryption, RSA encryption and decryption, the equation

References:

1. David M. Burton, Elementary Number Theory, Tata McGraw-Hill. 2. Neville Robbins, Beginning Number Theory, Narosa Publishing House Pvt. Ltd.

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M. Sc. Course in Mathematics
SEMESTER-IV
Course Code: PG-MATH-E-403
Course title: Graph Theory and Algorithm-II
Elective Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 3:1:0

Directed graphs: Directed graphs and binary relation, directed walks, trails, paths and connectedness, Euler digraphs, Characterization of Euler digraph. Acyclic digraphs and decyclization. Tournaments and their properties, Strong tournament. Topological sorting of the vertices of a tournament and for general acyclic digraphs.

Power of Graphs and Line graph: Hamiltonian-connected graphs, the square and cube of a graph. Definition and characterization of line graphs. Forbidden subgraphs of line graphs. The total graph of a graph.

Edge colouring: Edge colouring and chromatic index, Konigs theorem and chromatic index of a complete graph.

Clique and Stable set: Clique number, clique cover number and stability number of a graph. Definition of a Perfect graph. Perfect graph Theorem (Proof not required).

Triangulated graphs: Characterization of triangulated graphs with perfect scheme and minimal vertex separator. Transitive orientation and comparability graphs.

Interval Graphs: Intersection graph, definition and characterizations of an interval graph. Some application of interval graphs.
Ramsey Theory: Ramsey theorem, A party problem, Definition and some examples of Ramsey numbers, Ramsey Graph.

References
[1] G. Chartrand, L. Lesniak and P. Zhang; Graphs and Digraphs; Chapman and Hall, 2011.
[2] D. B. West; Introduction to Graph Theory; Prentice Hall of India, New Delhi; 2012.
[3] R. Diestel; Graph Theory; Springer-Verlag, Berlin, 2005.
[4] M. C. Golumbic; Algorithmic Graph Theory and Perfect Graph; Elsevier, 2004

Rajib Mukherjee

Contd… **Signature of the coordinator**

M. Sc. Course in Mathematics
SEMESTER-IV
Course Code: PG-MATH-E-404
Course title: Mathematical Biology-II
Elective Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 3:1:0

Dynamic Modeling with Difference Equations. The Malthusian Model. Non-linear Models. Analyzing Non-linear Models. Variations on the Logistic Model. Discrete and Continuous Models.

. **Linear Models of Structured Populations**. Linear Models and Matrix Algebra. Projection Matrices for Structured Models. Eigenvectors and Eigenvalues. Computation of Eigenvectors and Eigen values.

Non-linear models of Interactions. A simple Predator-Prey Model. Equilibria of Multi population Models. Linearization and Stability. Positive and Negative Interactions.

Modelling Molecular Evolution. Background on DNA. An Introduction to Probability. Conditional Probability. Matrix Models of Base Substitution. Phylogenetic Distances.

Constructing Phylogenetic Trees. Phylogenetic Trees. Tree Construction: Distance Methods – Basics. Tree Construction: Distance Methods – Neighbour Joining. Tree Construction: Maximum Parsimony.

Infectious Disease Modelling. Elementary Epidemic Models. Threshold Values and Critical Parameters. Variations on a Theme. Multiple Populations and Differentiated Infectivity.

References:

1. Elizabeth A. Allman and John A. Rhodes: Mathematical Models in Biology: An Introduction. Cambridge University Press (2004)

Rajib Mukherjee

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Signature of the coordinator

M. Sc. Course in Mathematics
SEMESTER-IV
Course Code: PG-MATH-E-405
Course title: Differential Geometry II
Elective Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 3:1:0

Tensor Algebra:

Finite Dimensional Real Linear Spaces, Their Subspaces and Dual Spaces. Summation Convention,

Change of Bases, Contravariant and Covariant Vectors. Multilinear Functionals, Tensor Spaces, Algebra of Tensors. Symmetric and Skew-Symmetric Tensors. Exterior Algebra.

Manifolds:

Definition and Examples. Differentiable Curves. Submanifolds. Tangents. Differential of a Map.

Vector Analysis on Manifolds:

Vector and Tensor Fields, Integral Curves and Flows, Lie Bracket. One Parameter Group of Transformations. Exponential Maps.

Linear Connections:

Linear Connections, Their Torsion and Curvature.

Riemannian Manifolds:

Riemannian Manifolds. Curvature Tensor, Ricci Tensor, Scalar Curvature, Sectional Curvature.

References:

1. Bishop, R.L., Goldberg, S.I., Tensor Analysis on Manifolds, Macmillan, 1968.
2. Hicks, N.J., Notes on Differential Geometry, Van Nostrand. 1965.
3. Kumaresan, S., Differential Geometry and Lie Groups, Hindusthan Book Agency, 2002.
4. Boothby, W.M., An Introduction to Differentiable Manifolds and Riemannian Geometry, Academic Press, 1975.

Rajib Mukherjee

Contd… **Signature of the coordinator**

M. Sc. Course in Mathematics
SEMESTER-IV
Course Code: PG-MATH-E-406
Course title: Fluid Mechanics-II
Elective Course; Credit-4; Full Marks-50
Course wise Class (L+T+P): 3:1:0

Irrotational Motion in Two Dimensions: General motion of a cylinder in two dimensions, Motion of a cylinder in a uniform stream, Liquid streaming past a fixed circular cylinder and two coaxial cylinders, Equations of motion of a circular cylinder, Circulation about a moving cylinder, Conjugate function, Elliptic cylinder, Liquid streaming past a fixed elliptic cylinder, Elliptic cylinder rotating in an infinite mass of liquid at rest at infinity, Circulation about an elliptic cylinder, Kinetic energy, Blasius theorem and its application, Kutta and Joukowski theorem, D'Alemberts paradox, Application of conformal mapping.

Viscous Flow: Field equations, Navier-Stokes equations, Vorticity and circulation in viscous fluids, Reynolds number, Boundary conditions, Flow of a viscous fluid with free surface on an inclined plane, Flow between parallel plates, Flow through pipes of circular, elliptic section under constant pressure gradient, Laminar flow between concentric rotating cylinder, Steady motion of a viscous fluid due to a slowly rotating sphere, Unsteady motion of a flat plate, Pulsatile flow between parallel surfaces, Prandtl's concept of boundary layer. Boundary layer flow along a flat plate, Momentum and energy integral equation for the boundary layer, Von Karman Pohlhausen method, Turbulence, Calculation of Turbulent BL.

References:

1. Prandt, L., Essential of fluid dynamics, Springer, 2004
2. White, F.M., Viscous Fluid Flow, McGraw Hill, 1991.
3. Panton, R.L., Incompressible Flow, John Wiley and Sons, 1984.
4. Rosenhead, L., Laminar Boundary Layer, Dover, 1988.
5. Sherman, F.S., Viscous Flow (McGraw Hill).
6. Pai, S.I., Viscous Flow Theory, D.Van Nostrand, 1997.
7. Schlichting, H., Boundary Layer Theory, Springer, 2001.
8. Chorlton, F., Text Book of Fluid Dynamics, CBS Publ.
9. Love, A.E., A treatise on mathematical theory of elasticity, McGraw Hill Book Co., 1956.
10. Kondepudi, D., Prigogine, I., Modern thermodynamics, John Wiley and Sons, Inc., 1998.
11. Landau, L.M., Lifshitz, E.M., Fluid Mechanics, Butterworth Heinemann, 2005.
12. Batchelor, G.K., An introduction to fluid dynamics, Cambridge university press, 2000.
13. Yuan, S.W., Foundations of fluid mechanics, Prentice-Hall, 1970.
14. Bansal, R.K., A Textbook of Fluid Mechanics, Laxmi Publications, 2017.

Rajib Mukherjee

Signature of the Coordinator
Department of Mathematics
Murshidabad University