Maulana Abul Kalam Azad University of Technology, West Bengal
Course: M.Sc in Applied Mathematics,
Effective from Academic Session: 2021-22
Duration: 2 Years (4 semesters); Level: Post graduation; Type: Degree

PREAMBLE TO THE PROGRAM MSC IN APPLIED MATHEMATICS AT MAKAUT, WB

CONTEXT

The technologies that are driving economic growth in the early 21st century include AI/ML and Data Science & Analytics. And the success of these technologies rest on the foundation of applied mathematical and statistical science. Consequently, there is a growing demand in the economy for high-end knowledge workers trained in applied mathematics and statistics. As a result, we are noticing a rising desire among our aspiring youth to enroll in higher education programs that focus on these areas of current interest. The decent size of enrolment in the debut batch of our MSc (Applied Statistics & Analytics) introduced in AY 2020-21 is an exhibit in support of this trend.

It is time for the School of Natural, Applied & Social Sciences to introduce it sequel, namely MSc in Applied Mathematics in AY 2021-22 offered from its constituent Department of Applied Science.
Its curriculum has been designed with an open and modern mind, referring to similar programs in premier national and international universities as well as taking inputs from corporate practitioners.

Program Description

MSc in Applied Mathematics is a two-year, four-semester fulltime post graduate degree program. Total Credit: Ninety Four (94).

Eligibility for Admission

Bachelor's degree in Science or Engineering of at least three-years duration from a UGC/AICTE recognized University/Institute with at least one of the subjects Mathematical/ Statistical/ computational sciences in undergraduate level or equivalent. Admission will be through the Common Entrance Test (CET) of MAKAUT following the merit list of qualified candidates.

Intake Limit

Proposed intake at introduction is 30 which may be upgraded to 60 subsequently on demand.

Program Design & Positioning in Higher Education Space

Existing similar programs offered by other universities in the state of West Bengal fail to balance the demands of academic and professional worlds, but rather incline steeply to academics. Evidently there is an inviting gap and urgent need to frame a curriculum which would prepare students for better employability and flexibility in career choice. The proposed program of MSc in Applied Mathematics is crafted to exploit this niche. It will bridge the gap between the evolving demands of the professional world and the applied mathematical skills of graduate students.

Program Highlights and Unique Features

It is a two-year post graduate degree program with a well-balanced curriculum between applicable Mathematics and its applications. The specialization topics are mostly industry oriented or interdisciplinary, which act as a bridge between academia and industries and are offered through electives. Emphasis is given on solving real life problems in various application domains using computational tools. The application domains include data science and machine learning, digital signal & image processing, computational fluid dynamics, mathematical biology & epidemiology, etc. Academic delivery employs modern pedagogical tools, such as case-based teaching, problem-based learning, etc. Students will engage in real-life project work right from the very first semester, culminating in a capstone project in the final year. The program will be administered with close connection with corporate practitioners.

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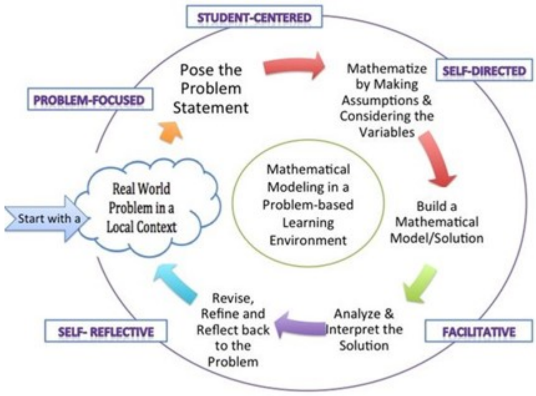
Modern Pedagogy

The teaching-learning practice of this program is student-centric and problem-focused. Academic delivery employs modern pedagogical tools, such as *case-based teaching, problem-based learning, project-based learning*, etc. Students will engage in *real-life project work right from the very first semester*, which will culminate in a capstone project in the final year. *The program will be administered with close connection with corporate practitioners*.



Learning Resources

Classic texts and modern books, journal articles, interactive simulations (such as Explorable Explanations, PhET, Wolfram Projects, etc.), Multimedia (such as 3Blue 1Brown), MOOCs, Webinars, Desmos, GeoGebra, Excel, MatLab, and many more.

Faculty Strength

The mathematical & statistical sciences unit boasts of nine fulltime university faculty members led by a Nehru-Cambridge Scholar. Six are doctoral degree holders. Two are full professors.

Career Prospects

The curriculum has been designed to *cater to academia as well as professional fields of data-driven, computer-aided business environments including R&D*. Potential employers are going to be the IT/ITeS sector, Consulting Companies, Banking Sector, NBFCs, Investment Companies, Education Sector, etc.

Fee Structure

ITEM	AMOUNT, Rs	ITEM	AMOUNT, Rs
Admission Fee	4000	Development Fee	1100
Tuition Fee per Sem	20000	Caution Money	8000
Number of Semesters	*4*	Registration Fee	500
Total Tuition Fee	80000	Exam Fee per Sem	1200
Lab Fee (Unit)	1000	Total Exam Fee	4800
Total Lab Fee	2000		
Library Fee per Sem	600	**Admission Time Payment**	**34700**
Total Library Fee	2400	**Total Program Fee**	**94800**

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Due Diligence

In addition to the guidelines and examples of the University Grants Commission (UGC), the curricula and syllabi of the following institutes of higher education were consulted before designing this curriculum and drafting the syllabus.

University of Massachusetts Amherst
https://www.math.umass.edu/graduate/applied-ms

Columbia University in the City of New York
https://www.apam.columbia.edu/programs/applied-mathematics/master

Northeastern University
https://www.northeastern.edu/graduate/program/master-of-science-in-applied-mathematics-14241/

Illinois Institute of Technology, Chicago
http://bulletin.iit.edu/graduate/colleges/computing/applied-mathematics/ms-applied-mathematics/#programrequirementstext

Jadavpur University
http://www.jaduniv.edu.in/upload_files/dept_file/1283169609-2.pdf

University of Calcutta
https://www.caluniv.ac.in/syllabus/mathamatics.pdf

IIT-Kharagpur
http://www.iitkgp.ac.in/department/MA

IIT(ISM) Dhanbad
https://www.iitism.ac.in/index.php/Departments/postgrad_apmat

IIEST Shibpur
https://www.iiests.ac.in/IIEST/AcaUnitDetails/MATHS

Credit Transfer Options:
Following current trends and practices of UGC and MAKAUT, WB, a student may be permitted to adopt equivalent MOOCS, in place of a particular subject in the course curriculum from the basket of courses as would be prescribed by University from time to time, with transfer of credit.
A suggested MOOC-basket (indicative, not exhaustive) has been appended to the syllabus for illustrative purpose.

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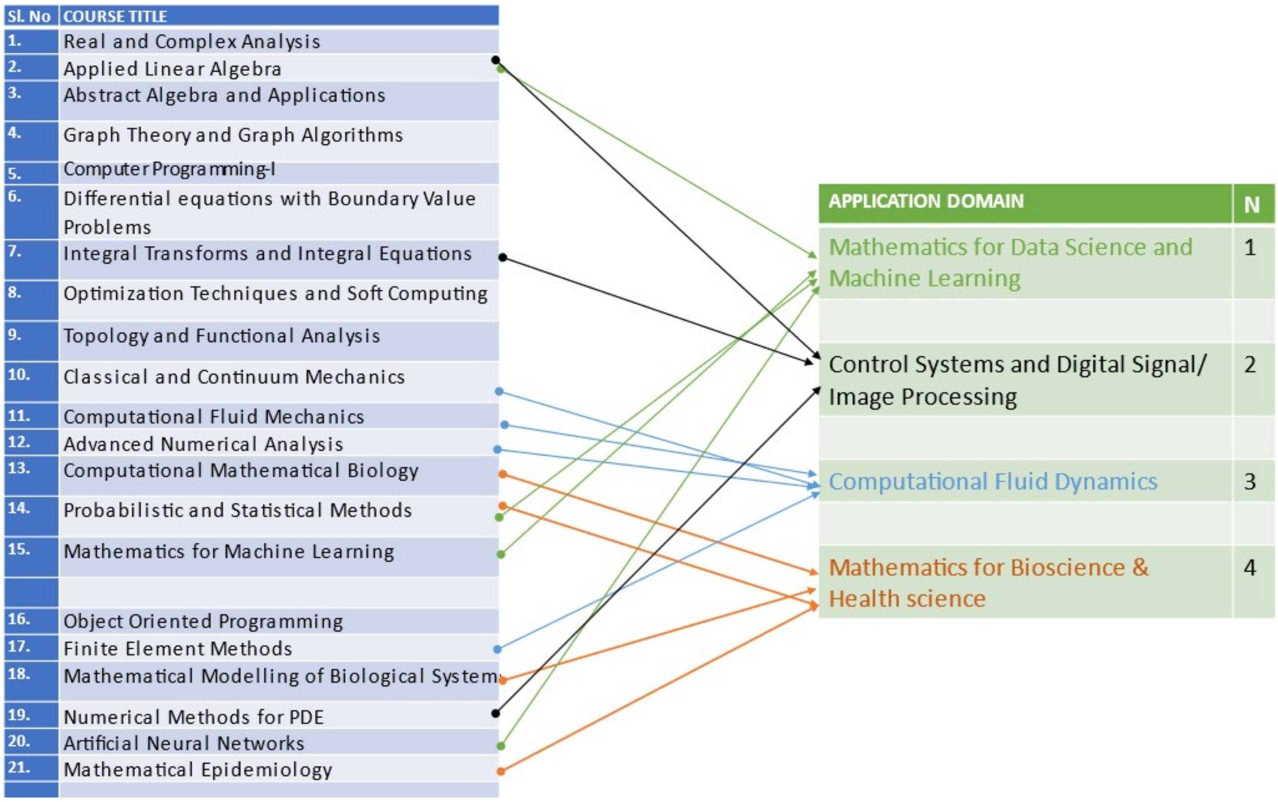
Curricular Design: Graphically Illustrating Individual Courses Mapping into indicative Application Domains



Summary

Recent years have witnessed a job market with escalating demand for applied mathematicians complemented with computational skills. This trend is here to stay for a while because the drivers of technology in the early 21st century, namely AI/ML, Analytics, Data Science, etc. are all thriving on the foundation of applied mathematical and statistical sciences.

Similar academic programs currently offered by other universities in the state of West Bengal do not balance the demands of academic and professional worlds, but rather incline more to academics. Evidently there is an inviting gap and urgent need to prepare *a mathematics curriculum that would prepare students for upscale employability*. This program of MSc in Applied Mathematics has been carefully crafted to exploit this niche. It is designed to bridge the gap between the evolving demand of the professional world and the applied mathematical skills of university graduates.

MSc in Applied Mathematics is a two-year fulltime post graduate degree program with a well-balanced curriculum between applicable mathematics and its applications. *The specialization topics are mostly industry oriented or interdisciplinary* which act as a bridge between academia and industry and are offered through electives. *Emphasis is given on solving real life problems in various application domains using computational tools*. The application domains include data science and machine learning, digital signal & image processing, computational fluid dynamics, mathematical biology & epidemiology, etc. *The Program boasts of nine fulltime university faculty members led by a Nehru-Cambridge Scholar.*

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Program outcomes for MSc in Applied Mathematics

Upon completion of this 2-year post-graduate degree program, the learners will be able to

PO1. Appreciate & articulate the symmetry & patterns that underlie & govern appearance & behavior of objects & systems in natural as well as built environments.

PO2. Model real-world phenomena into mathematical formulations, solve the resulting mathematical problems, and subsequently interpret the solutions back to the real-world as applicable recommendations.

PO3. Deploy a rich *port folio* of advanced mathematical techniques using contemporary software tools for the purpose of solving real-life problems.

PO4. Demonstrate proficiency in the knowledge of mathematical principles underlying archetypical problems in real-life application domains.

PO5. Demonstrate efficacy in the use of numerical techniques & computational tools for solving problems, assessing risks, and exploring opportunities in real life applications.

PO6. Interact with fellow professionals of their own and other fields of science, engineering, and humanities through collaborative engagement.

PO7. Contribute their part in addressing ‘big’ scientific, technical, and societal issues which demand interdisciplinary as well as transdisciplinary efforts to solve and resolve.

PO8. Critically read, critique, and evaluate the merit of scientific & technical documents that concern application of mathematical science.

PO9. Write scientific & technical documents, such as essays, research & review articles, project proposals & reports, theses, etc. in the domain of mathematical science.

PO10. Acquire on their own initiative new knowledge & skills of (applied) mathematics to stay current in their profession.

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Semester 1:

Course Code (CoE Office)	Course Code	Course Name	Course Type	Marks	Hours Per Week			Credit
					L	T	P	
Theory								
MS-AM101	MS-AM401	Real and Complex Analysis	CC	100	3	1	0	4
MS-AM102	MS-AM403	Applied Linear Algebra	CC	100	3	1	0	4
MS-AM103	MS-AM405	Classical Mechanics	CC	100	3	1	0	4
MS-AM104	MS-AM407	Graph Theory and Graph Algorithms	CC	100	3	1	0	4
MS-AM105	MS-AM409	Computer Programming with Python	SEC	100	2	0	0	2
Practical								
MS-AM191 (Lab)	MS-AM491 (Lab)	Applied Linear Algebra and Graph Algorithms Lab (Using Python and MATLAB)	SEC	100	0	0	4	2
MS-AM192 (Lab)	MS-AM493 (Lab)	Python Programming Lab	SEC	100	0	0	4	2
Sessional								
MS-AM193	MS-AM495	Term Project - I	SEC	100	0	0	4	2
			Total	**800**				**24**

Semester 2:

Course Code (CoE Office)	Course Code	Course Name	Course Type	Marks	Hours Per Week			Credit
					L	T	P	
Theory								
MS-AM201	MS-AM402	Differential equations with Boundary Value Problems	CC	100	3	1	0	4
MS-AM202	MS-AM404	Advanced Numerical Analysis and CFD	CC	100	3	1	0	4
MS-AM203	MS-AM406	Continuum Mechanics and Introduction to Fluid Dynamics	CC	100	3	1	0	4
MS-AM204	MS-AM408	Abstract Algebra and Applications	CC	100	3	1	0	4
MS-AM205	MS-AM410	Research Methodology and IPR	VAC	100	2	0	0	2
MS-AM206	MS-AM412	Elective-I	DSE	100	3	1	0	4

Practical								
MS-AM291 (Lab)	MS-AM492 (Lab)	Advanced Numerical Analysis Lab	SEC	100	0	0	4	2
MS-AM292 (Lab)	MS-AM494 (Lab)	Computational Fluid Dynamics Lab	SEC	100	0	0	4	2
Sessional								
MS-AM293	MS-AM496	Term Project - II	SEC	100	0	0	4	2
			Total	**800**				**28**

Semester 3:

Course Code (CoE Office)	Course Code	Course Title	Course Type	Marks	Hours Per Week			Credit
					L	**T**	**P**	
Theory								
MS-AM301	MS-AM501	Topology and Functional Analysis	CC	100	3	1	0	4
MS-AM302	MS-AM503	Data Science-1: Machine Learning	CC	100	3	1	0	4
MS-AM303	MS-AM505	Integral Transforms and Integral Equations	CC	100	3	1	0	4
MS-AM304	MS-AM507	Computational Biology	CC	100	3	1	0	4
MS-AM305	MS-AM509	Elective-II	IDE	100	3	1	0	4
Practical								
MS-AM391 (Lab)	MS-AM593 (Lab)	Machine Learning Lab	SEC	100	0	0	4	2
MS-AM392 (Lab)	MS-AM595 (Lab)	Differential Equation and Integral Transform Lab	SEC	100	0	0	4	2
Sessional								
MS-AM393	MS-AM595	Term Project-III	SEC	100	0	0	4	4
			Total	**800**				**28**

Semester 4:

Course Code (CoE Office)	Course Code	Course Title	Course Type	Marks	Hours Per Week			Credit
					L	**T**	**P**	
Theory								
MS-AM401	MS-AM502	Probabilistic and Statistical Methods	CC	100	3	1	0	4

MS-AM402	MS-AM504	Operations Research: Optimization Techniques and Soft Computing	CC	100	3	1	0	4
Practical								
MS-AM491 (Lab)	MS-AM592 (Lab)	Optimization Techniques and Soft Computing Lab	SEC	100	0	0	4	2
Sessional								
MS-AM492	MS-AM594	Capstone Project (Addressing a real-life problem)	SEC	200	0	0	16	8
			Total	**500**				**18**

CC: Core Course, **SEC:** Skill Enhancement Course, **IDE:** Interdisciplinary Elective Course, **DSE:** Discipline Specific Elective Course, **VAC**: Value Added Course

Students are recommended to go for internship/ industrial training during semester break (between II & III)

List of Electives:

Elective- I (DSE):

Sr. No.	Course Code (CoE Office)	Course No.	Course Name	L	T	P	Credit
1	MS-AM206A	MS-AM412A	Number Theory and Cryptography	3	1	0	4
2	MS-AM206B	MS-AM412B	Operations Research: Queuing Theory and Game Theory	3	1	0	4
3	MS-AM206C	MS-AM412C	Fuzzy Sets and Applications	3	1	0	4
4	MS-AM206D	MS-AM412D	Differential Geometry	3	1	0	4
5	MS-AM206E	MS-AM412E	Theory of Computation and Finite Machine Analysis	3	1	0	4

Elective –II (IDE):

Sr. No.	Course Code (CoE	Course No.	Course Name	L	T	P	Credit
1	MS-AM305A	MS-AM509A	Quantum Information and Computation	3	1	0	4
2	MS-AM305B	MS-AM509B	Mathematical Epidemiology	3	1	0	4
3	MS-AM305C	MS-AM509C	Mathematical Modelling of Biological Systems	3	1	0	4
4	MS-AM305D	MS-AM509D	Astrophysics and Cosmology	3	1	0	4

5	MS-AM305E	MS-AM509E	Advanced Data Science	3	1	0	4
6	MS-AM305F	MS-AM509F	Mathematics for Finance	3	1	0	4
7	MS-AM305G	MS-AM509G	Actuarial Science	3	1	0	4

Suggested MOOCS courses:
Computational Biology

https://www.coursera.org/specializations/genomic-data-science

Mathematical Epidemiology

https://www.coursera.org/specializations/infectious-disease-modelling

https://www.coursera.org/learn/developing-the-sir-model

https://www.coursera.org/learn/validity-bias-epidemiology

Mathematical Modelling of Biological system

https://www.coursera.org/learn/dynamical-modeling

Number Theory & Cryptography

https://www.coursera.org/learn/number-theory-cryptography

https://www.coursera.org/specializations/introduction-applied-cryptography

Probabilistic and Statistical Methods:

https://www.coursera.org/learn/statistical-thinking-applied-statistics?
https://onlinecourses.nptel.ac.in/noc21_ma66/preview

Quantum Information & Computation:

https://www.coursera.org/learn/physical-basis-quantum-computing

https://www.coursera.org/learn/quantum-computing-lfmu

https://www.coursera.org/learn/quantum-computing-algorithms

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Semester-1:

Real and Complex Analysis	**Course Code: MS-AM101** **4 Credits, 100 marks**

Course Objectives:

1. To expose the students to the basics of real analysis and to recognize convergent, divergent, bounded, Cauchy and monotone sequences.
2. To define the real numbers, least upper bounds, and the triangle inequality, define functions between sets; equivalent sets; finite, countable and uncountable sets.
3. Will perform basic mathematical operations (arithmetic, powers, roots) with complex numbers in Cartesian and polar forms.
4. Ability to analyze with functions (polynomials, reciprocals, exponential, trigonometric, hyperbolic) of single real/complex variable and its synthesis and describe mappings in the complex plane.

Group-A: Real Analysis

Module 1: Review of basic concepts 4L
Review of Limit points, Compactness, Bolzano-Weierstrass Theorem, Heine-Borel Theorem and its illustration with the help of applications, Sequence and Series, Power series, Sequence of Functions and associated results.

Module 2: Bounded Variation 5L
Functions of Bounded Variation and their properties, Decomposition theorem, Differentiation of a function of bounded variation, Absolutely Continuous Function, Representation of an absolutely continuous function by an integral.

Module 3: Riemann-Stieltjes integrals 4L
Riemann-Stieltjes integral as limit of a sum, Properties, Relation between Riemann and Riemann-Stieltjes integrals.

Module 4: 8L
i) Measures: Inner and outer measure of a set, Measurable sets, Measurable functions, Sequence of Measurable functions and Convergence of Measurable functions

ii) The Lebesgue Integral: Lebesgue Measure and Lebesgue Integral, Comparison of Riemann and Lebesgue Integral, Monotone convergence theorem. Fatou's lemma, Lebesgue dominated convergence theorem.

Group-B: Complex Analysis

Module 5: 3L
Complex numbers, Topology of the complex plane, Stereographic projection.
Analytic functions, Cauchy-Riemann equations, Harmonic Functions, Zeros of analytic functions, multiple valued functions, Branch cuts.

Module 6: 6L

Curves in the complex plane, Complex Integration, Basic Properties of Complex Integral, Jordan's Lemma. Cauchy's theorem, Morera's theorem, Cauchy integral formula, Maximum modulus principle, Schwarz Lemma, Liouville's theorem, Fundamental theorem of algebra.

Module 7: 5L

Series, Uniform convergence, Properties of uniformly convergent series, Power series, Taylor series and Analytic continuation: Direct analytic continuations, Uniqueness of analytic continuation along a curve, Laurent series.

Module 8: 6L

Singularities, Classification of singularities, Cauchy's residue theorem.
Evaluation of some real integrals, The Argument theorem, Rouche's theorem, Conformal mapping, Mobius transformation.

References:

1. Bartle and Sherbert, Introduction to Real Analysis, Third edition, Wiley-India.
2. V.L. Ahlfors, Complex Analysis, McGraw-Hill Inc.
3. R. V. Churchill and J W Brown, Complex Variables and Applications, McGraw-Hill Inc
4. S. Ponnusamy, Foundations of Complex Analysis, Narosa, 1995.
5. I.P.Natanson, Theory of functions of a real variables, Dover Book on Mathematics.
6. H.L. Royden and P.M. Fitzpatrick, Real Analysis, Fourth Edition, Prentice Hall.
7. Amritava Gupta, Real and Abstract Analysis, Academic Publishers.

Relationship of CO with PO mapping:

CO	**PO**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Real and Complex Analysis (MS-AM101)										
CO1: To expose the students to the basics of real analysis and to recognize convergent, divergent, bounded, Cauchy and monotone sequences.	S	M	M	M	M	L	L	M	M	L
CO2: To define the real numbers, least upper bounds, and the triangle inequality, define functions between sets; equivalent sets; finite, countable and uncountable sets.	S	S	L	M	L	L	M	M	M	L
CO3: Will perform basic mathematical operations (arithmetic, powers, roots) with complex numbers in Cartesian and polar forms.	S	S	M	S	M	M	L	M	M	M
CO4: Ability to handle with functions (polynomials, reciprocals, exponential, trigonometric, hyperbolic) of single complex variable and describe mappings in the complex plane.	S	S	M	M	M	M	S	M	M	S

S- Strong; M-Medium; L-Low

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Applied Linear Algebra	**Course Code: MS-AM102**
	4 Credits, 100 marks

Course Objectives:

1. To gain computational techniques and algebraic skills essential for the study of systems of linear equations, matrix algebra, vector spaces, eigenvalues and eigenvectors, orthogonality and diagonalization.
2. To gain knowledge and ability for visualization, spatial reasoning, as well as geometric properties and strategies to model, solve problems, and view solutions, especially in R^2 and R^3, as well as conceptually extend these results to higher dimensions.
3. To learn analyzing and application of algorithms of linear algebra to data science and particularly in machine learning.
4. To use appropriate technology, to enhance and facilitate mathematical understanding of data with a view to analyze, as well as presenting acceptable solutions.

Module 1: General introduction and review of basic concepts: (5L)
Review of vector spaces, linear independence, bases, dimension, subspaces. Vector space in R^n: System of linear equations, row space, column space and null space. Four fundamental spaces and their significance, relation between rank and nullity, Consistency theorem, Basis from a spanning set and independent set.

Module 2: Linear transformations and Matrices: (6L)
Linear transformations, matrix representations, range and null space, invertibility, solution of linear equations, eigenvalues and eigenvectors, similarity transformations, spectral invariance, diagonalizability, application in webpage ranking.

Module 3 : Inner products and Associated Norms: (7L)
Inner products and its properties, Norms, equivalence of norms, orthogonality, orthonormal bases, orthogonalization, Gram-Schmidt orthogonalization process. Linear transformations on inner-product spaces. Orthogonal compliments, orthogonal projection, orthogonal subspace and corresponding representation theorem.

Module 4: Symmetric and Positive-Definite Transformations: (6L)
Symmetric transformations, Symmetric and Hermitian matrices, Linear equations revisited, Orthonormality of eigenvectors, Spectral decomposition theorem, Positive and positive-definite transformations and matrices, Quadratic forms. Unitary transformations, orthogonal and unitary matrices.

Module 5: Matrix Decompositions: (6L)
LU, QR, Cholesky, Schur and Singular value decompositions with applications, Non-negative matrix factorization and its and Applications in Clustering and Recommender Systems.

Module 6: Least Square Problem: (6L)
Solution of linear least squares problems using matrix method, Constrained least squares applications, Moore-Penrose inverse; Solution of Rank deficient least squares problems.

Module 7: Linear Models: (4L)
Gauss Markov Model, Estimable function, error function, BLUE, Gauss Markov theorem. Correlated set-up, least squares estimate with restriction on parameters.

References:

1. G. Strang, Linear Algebra and its Application, 4th edition, Cengage
2. S. Boyd and L. Vandenberghe, Introduction to Applied Linear Algebra: Vector, Matrices and Least Squares, Cambridge University Press.
3. P. J. Olver and C. Shakiban, Applied Linear Algebra by, second Edition, Springer
4. G. H. Golub and C. F. Van Loan, Matrix Computations, 3rd Edition, John Hopkins University Press, 1996
5. G. A.F. Seber, Linear Regression Analysis, 2nd Edition, Wiley, 2003
6. S. R. Searle, Linear Models, 2nd Edition, Wiley
7. C.R. Rao, Linear Statistical Inference and its applications, 2nd Edition, Wiley

Relationship of CO with PO mapping:

CO	PO									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Applied Linear Algebra (MS-AM102)										
CO1: To gain computational techniques and algebraic skills essential for the study of systems of linear equations, matrix algebra, vector spaces, eigenvalues and eigenvectors, orthogonality and diagonalization.	S	S	S	M	S	S	M	M	M	M
CO2: To gain knowledge and ability for visualization, spatial reasoning, as well as geometric properties and strategies to model, solve problems, and view solutions, especially in R^2 and R^3, as well as conceptually extend these results to higher dimensions.	S	S	S	M	S	M	S	M	M	M
CO3: To learn analyzing and application of algorithms of linear algebra to data science and particularly in machine learning.	S	S	S	S	M	M	M	S	M	S
CO4: To use appropriate technology, to enhance and facilitate mathematical understanding of data with a view to analyse, as well as presenting acceptable solutions.	M	S	S	M	M	S	M	L	L	M

S- Strong; M-Medium; L-Low

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Classical Mechanics	**Course Code: MS-AM103** **4 Credits, 100 marks**

Course Objectives:

1.The students will be able to apply the Variational principles to real physical problems.

2.The students will be able to model mechanical systems, both in inertial and rotating frames, using Lagrange and Hamilton equations.

3. Students will know the concepts of classical mechanics and demonstrate a proficiency in the fundamental concepts in this area of science.

4. Students will be able to solve problems using their knowledge and skills in modern physics. They will use critical thinking skills to formulate and solve quantitative problems in applied physics.

Module 1 12L

Survey of elementary principles: review of the Newtonian mechanics, constraints, D'Alembert's principle, Lagrange's equation, Its application to simple problems. The equation of motion, the equivalent one-dimensional problem, classification of orbits, Virial theorem, Differential equation for the orbit, inverse square law of force, scattering in central force field. Variational Principles and Lagrange's equations: calculus of variations, Hamilton's principle, derivation of Lagrange's equation from Hamilton's principle, its application, conservation and symmetry property.

Module 2 12L

Small oscillations: formulation of the problem, eigen value equation, principal axis transformation, normal coordinates, triatomic molecule free vibration, forced and damped vibrations. orthogonal transformation, the Eulerian angles, Euler's theorem, infinitesimal rotation, tensors and dyadic, force free motion of rigid body, the heavy symmetrical top. Hamilton's equation of motion: Legendre transformations and Hamilton's equation, cyclic coordinates, Routh's procedure, physical significance of Hamiltonian. Examples of canonical transformations, Lagrange and Poisson Brackets.

Module 3 **10L**

Special theory of relativity, Galilean transformation, Basic postulates of relativity, Lorentz transformation, Consequences of Lorentz transformation, Relativistic momentum: variation of mass with velocity, relativistic force, work and energy.

Module 4 **10L**

Variation of functional, Necessary and sufficient conditions for extrema, Euler-Lagrange's equations and its applications: Geodesic, minimum surface of revolution, Brachistochrone problem and other boundary value problems in ordinary and partial differential equations.

Reference:

1. H. Goldstein, (2011), Classical Mechanics, Pearson New
2. N.C. Rana, and P.S. Joag, (1991), Classical Mechanics, Tata McGraw Hill
3. L.D. Landau, and E.M. Lifshitz, (1960), Mechanics, Pergamon Press
4. L. Meirovitch, (1999), Methods of Analytical Dynamics, McGraw Hill
5. K. S., Srinivasa Rao, (2003), Classical Mechanics, Universities press

6. J. V. Jose, and E. J., Saletan, (2002), Classical Dynamics: A Contemporary Approach, Cambridge University Press.

Relationship of CO with PO mapping:

CO	PO									
	1	2	3	4	5	6	7	8	9	10
Classical Mechanics (MS-AM103)										
CO1: The students will be able to apply the Variational principles to real physical problems.	S	S	M	M	S	S	M	M	M	M
CO2: The students will be able to model mechanical systems, both in inertial and rotating frames, using Lagrange and Hamilton equations.	S	S	S	S	S	M	S	M	M	M
CO3: Students will know the concepts of classical mechanics and demonstrate a proficiency in the fundamental concepts in this area of science.	S	S	M	S	M	M	M	S	M	S
CO4: Students will be able to solve problems using their knowledge and skills in modern physics. They will use critical thinking skills to formulate and solve quantitative problems in applied physics.	M	S	M	M	M	S	M	L	L	M

S- Strong; M-Medium; L-Low

Graph Theory and Graph Algorithms	**Course Code: MS-AM104** **4 Credits, 100 marks**

Course Objectives:

1. To understand and apply the fundamental concepts in graph theory
2. To apply graph theory-based tools in solving practical problems
3. To introduce the basics of graphs and combinatory required for VLSI design and Optimization
4. To understand the various types of graph Algorithms and graph theory properties
5. To distinguish the features of the various tree and matching algorithms
6. To analyze web data on information propagation.

Module 1 **10L**

Basic definitions, Degree of vertices, Graph isomorphism, Complement of a graph. Self complementary graph, eccentricity properties of graphs. Tree, Spanning tree, shortest path algorithms: Dijkstra and Floyd algorithms, DFS-BFS algorithm, Connectivity: Strongly and weakly connected graphs with applications, Deadlock communication network. Eulerian and Hamiltonian graphs and their characterization.

Matrix representation of graph and digraphs.

Module 2 **8L**

Planar graphs, Euler's formula for connected and K-connected graphs, Two basic planer graphs K_5 and $K_{3,3}$. Homeomorphic graphs, Kuratowski's Theorem, Detection of planarity, Hopcroft-Tarjan Planarity Algorithm.

Matching theory, Maximal and maximum matching and algorithms for maximal matching. Perfect matching (only properties and applications to regular graphs). Halls Theorem, Stable matching and Gale-Shapley Algorithm.

Module 3 **10L**

Graph colouring: Vertex and edge colouring, Chromatic number and its bounds, Graph colouring algorithms: Greedy algorithm and Welsh-Powell algorithm, Chromatic polynomials: Properties and its determination,

Five-Colour and Four-Colour Theorem, Applications of graph colouring: Register allocation, Frequency range of GSM Mobile, Frequency assignment, Perfect graphs, interval graphs and their applications, Independence set and cliques**.**

Module 4 **10L**

Directed Graphs, Directed Paths, Directed Cycles, Applications: A Job Sequencing Problem, Designing an Efficient Computer Drum, Making a Road System One-way, Network-Flows , Cuts, The Max-Flow Min-Cut Theorem, Floyd–Warshall algorithm, Applications: Menger's Theorems.

Module 5 **6L**

Graph Mining and its applications: Motivation for Graph Mining, Web mining, centrality analysis, Link analysis algorithms, graph clustering and community detection, Node classification and Link prediction, Influential spreaders, Influence maximization, Geo-social and location-based networks.

References:

1. J. A. Bondy, and U.S.R, Murty, Graph Theory with Applications, Springer, 2008.
2. R. Diestel, Graph Theory (Graduate Texts in Mathematics). Springer-Verlag, 2000.
3. F. Harary, Graph Theory, CRC Press; 2019.
4. J. Clark, D. Holton, A First Look at Graph Theory- World Scientific Pub Com. 1991.
5. D. Easley and J. Kleinberg. Networks, Crowds, and Markets. Cambridge University Press, 2010.
6. A.L. Barabási. Network Science. Cambridge University Press, 2016

Relationship of CO with PO mapping:

CO	**PO**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Graph Theory and Graph Algorithms (MS-AM104)										
CO1: To understand and apply the fundamental concepts in graph theory.	S	S	M	M	S	S	M	M	M	M

CO2: To apply graph theory-based tools in solving practical problems.	S	S	S	S	S	M	S	M	M	M
CO3: To introduce the basics of graphs and combinatory required for VLSI design and Optimization.	S	S	M	S	M	M	M	S	M	S
CO4: To understand the various types of graph Algorithms and graph theory properties.	M	S	M	M	M	S	M	L	L	M
CO5: To distinguish the features of the various tree and matching algorithms.	S	S	M	S	S	S	M	L	L	M
CO6: To analyze web data on information propagation.	S	S	S	S	M	S	M	L	L	M

S- Strong; M-Medium; L-Low

Computer Programming with Python	**Course Code: MS-AM105** **2 Credits, 100 marks**

Course Objectives:

1. To Understand the principles of Python and acquire skills in programming in python.
2. Interpret the fundamental Python syntax and semantics and be fluent in the use of Python control flow statements.
3. To implement Python programs with conditionals and loops.
4. Represent compound data using Python lists, tuples, dictionaries, Files and modules.
5. To implement the python programming features in practical applications.
6. To develop the emerging applications of relevant field using Python (Data Science).

Module 1 **10L**

Basic concepts: Fundamentals of Python

Getting Started: Running Code in the Interactive Shell, Input, Processing and Output, Editing, Saving and Running a Script, Working of Python.

Variables, Expressions and Statements: Values and Data Types, Variables, Keywords, String Literals, Escape Sequences, Operators and Operands, Expressions and Statements, Interactive mode and Script mode, Order of Operations, Comments.

Python Operators and Operands: Arithmetic, Relational Operators and Comparison Operators -- Python Assignment Operators Short hand Assignment Operators -- Logical Operators or Bitwise Operators Membership Operators -- Identity Operators Operator precedence -- Evaluating Expressions

Module 2 **10L**

String Handling: String operations and indices Basic String Operations -- String Functions, Methods --

Delete a string -- String Multiplication and concatenation -- Python Keywords, Identifiers and Literals -- String Formatting Operator -- Structuring with indentation in Python -- Built-in String Methods-- Accessing Values in Strings -- Various String Operators -- Python String replace() Method -- Changing upper and lower case strings -- Using "join" function for the string -- Reversing String -- Split Strings

Control Structures: Boolean Expressions - Selection Control - If Statement- Indentation in Python- Multi-Way Selection – If-Elif statements--Iterative Control- For loop- While Statement- Infinite loops— Break and Continue Statements--Definite vs Indefinite Loops- Boolean Flags and Indefinite Loops.

Module 3 **12L**

List, Ranges & Tuples in Python: Lists are mutable - Getting to Lists -- List indices - Traversing a list - List operations, slices and methods - Map, filter and reduce - Deleting elements - Lists and strings - Understanding Iterators-- Generators, Comprehensions and Lambda Expressions:
1) Introduction 2) Generators and Yield 3) Next and Ranges
--Understanding and using Ranges - Advantages of Tuple over List -- Packing and Unpacking Comparing tuples -- Creating nested tuple Using tuples as keys in dictionaries -- Deleting Tuples Slicing of Tuple -- Tuple Membership Test Built-in functions with Tuple

Python Sets and Dictionaries: How to create a set -- Iteration Over Sets- Python Set Methods -- Python Set Operations Union of sets -- Built-in Functions with Set --Python Frozen set -- How to create a dictionary Python Hashing- Python Dictionary Methods -Copying dictionary and Updating Dictionary -- Delete Keys from the dictionary -- Dictionary items() Method --Sorting the Dictionary Python Dictionary in-built Functions -- Dictionary len() Method -- Variable Types Python List cmp() Method -- Dictionary Str(dict)

Module 4 **12L**

Python Functions: Program Routines- Defining Functions- More on Functions: Calling Value-Returning Functions- Calling Non-Value-Returning Functions- Parameter Passing - Keyword Arguments in Python - Default Arguments in Python- Scope and Lifetime of variables -- Nested Functions -- Passing functions to function.

Python Object Oriented: Overview of OOP - The self-variable --- Constructor -- Types Of Variables - Namespaces - Creating Classes and Objects - How to define Python classes- Python Namespace-- Inheritance -Types of Inheritance- How Inheritance works -- Python Multiple Inheritance -- Overloading and Over Riding --Types of Methods 1) Instance Methods 2) Static Methods 3) Class Methods -- Accessing attributes - Built-In Class Attributes - Destroying Objects - Abstract classes and Interfaces - Abstract Methods and Abstract class - Interface in Python - Abstract classes and Interfaces-- Access Modifiers-- Garbage Collection

Exception Handling: Errors in Python - Compile-Time Errors - Runtime Errors - Logical Errors -- What is Exception - Handling an exception *try….except…else try-finally* clause -- Argument of an Exception - Python Standard Exceptions - Raising an exceptions - User-Defined Exceptions

Module 5 **12L**

Python Regular Expressions: What is Regular Expression - Regular Expression Syntax -Understanding Regular Expressions - Regular Expression Patterns Literal characters -- Repetition Cases - Example of w+ and ^ Expression - Example of \s expression in re.split function Using regular expression methods --

Using re.match() - Finding Pattern in Text (re.search()) - Using re.findall for text Python Flags -- Methods of Regular Expressions

Objects and their use: Software Objects - Turtle Graphics – Turtle attributes-Modular Design: Modules - Top-Down Design - Python Modules - Text Files: Opening, reading and writing text files

Data Science Using Python: Numpy: Introduction to numpy - Creating arrays - Indexing Arrays - Array Transposition - Universal Array Function - Array Processing - Array Input and Output--- Pandas: What are pandas - Where it is used - Series in pandas - Index objects - Reindex - Drop Entry - Selecting Entries - Data Alignment - Rank and Sort - Summary Statics - Index Hierarchy-- Matplotlib: Introduction to Matplotlib - Data Visualization - Python for Data Visualization

References:

1. M. Lutz, Learning Python Powerful Object Oriented Programming, O'reilly Media 2018, 5th Edition.
2. T. A. Budd, Exploring Python, Tata MCGraw Hill Education Private Limited 2011, 1st Edition.
3. A. Downey, J. Elkner, C. Meyers, How to think like a computer scientist: learning with Python, 2012.
4. S. Taneja & N. kumar, Python Programming a Modular approach – A Modular approach with Graphics, Database, Mobile and Web applications, Pearson, 2017.
5. C. Satyanarayana M. Radhika Mani, B. N. Jagadesh, Python programming, Universities Press 2018.
6. K. A. Lambert, The Fundamentals of Python: First Programs, 2011, Cengage Learning, ISBN: 978-1111822705

Relationship of CO with PO mapping:

CO	PO									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Computer Programming with Python (MS-AM105)										
CO1: To Understand the principles of Python and acquire skills in programming in python.	S	S	S	M	S	S	M	M	M	M
CO2: Interpret the fundamental Python syntax and semantics and be fluent in the use of Python control flow statements.	S	S	S	S	S	M	S	M	M	M
CO3: To implement Python programs with conditionals and loops.	S	S	M	S	M	M	M	S	M	S
CO4: Represent compound data using Python lists, tuples, dictionaries, Files and modules.	M	S	M	S	M	M	M	L	M	M
CO5: To implement the python programming features in practical applications.	S	S	M	S	S	S	M	L	M	M
CO6: To develop the emerging applications of relevant field using Python (Data Science).	S	S	S	S	M	M	M	L	L	M

S- Strong; M-Medium; L-Low

Applied Linear Algebra and Graph Algorithms Lab (Using Python and MATLAB)	**Course Code: MS-AM191(LAB)** **2 Credits, 100 marks**

Course Objectives:

1. To apply different methods and techniques of linear algebra to determine eigenvalues and eigenvectors, factorization of matrices with relevant applications in Machine learning/Data Science.
2. To analyze different types of networks including electrical networks, distribution network, social networks.
3. To implement available algorithms of graph theory and linear algebra.

Chapter	Name of the topic	Hours
01	Direct data collection, Data Collection from web sources, Data cleaning, Data visualizations.	4
02	Basic Matrix operations, Various decompositions, Application of matrix algebra in real life problems.	2
03	Gram-Schmidt orthogonalization, Eigenvalues and Eigenvectors and Eigen decomposition of a square matrix.	4
04	Singular value decomposition and non-negative matrix factorization of any matrix.	4
05	Solution of a set of linear equations AX = B where B does not belong to C(A), by the method of least squares.	2
06	Minimum Cost Spanning Tree of a given undirected graph using Kruskal"s algorithm.	2
07	Minimum Cost Spanning Tree of a given undirected graph using Prim"s algorithm.	2
08	Shortest path using Dijkstra's algorithm	4
09	Algorithm for finding out chromatic number of a graph, matching in graphs.	4
10	The Traveling Salesperson Problem (TSP), A Greedy Algorithm, Maximum and minimum element in BST (Binary Search Tree)	4

References:

1. A. Drozdek, Data Structures and algorithm in C, Third Edition, Cengage Learning, 2012.
2. D. Samanta, Classic Data Structures, Prentice Hall of India.
3. A. M. Tenenbaum, Moshe J. Augenstein, YedidyahLangsam, Data Structures Using C, Second edition, PHI, 2009.
4. R. L. Kruse, Data Structures and Program Design, Pearson.

Relationship of CO with PO mapping:

CO	PO									
	1	2	3	4	5	6	7	8	9	10
Applied Linear Algebra and Graph Algorithms Lab (Using Python and MATLAB) (MS-AM191(LAB))										
CO1: To apply different methods and techniques of linear algebra to determine eigenvalues and eigenvectors, factorization of matrices with relevant applications in Machine learning/Data Science.	S	S	S	S	S	S	S	M	M	S
CO2: To analyze different types of networks including electrical networks, distribution network, social networks.	S	M	S	S	S	M	M	L	L	S
CO3: To implement available algorithms of graph theory and linear algebra.	S	M	S	S	S	M	M	M	M	S

S- Strong; M-Medium; L-Low

Python Programming Lab	**Course Code: MS-AM192(LAB)** **2 Credits, 100 marks**

Course Objectives:

1. To write, test, and debug simple Python programs.
2. To implement Python programs with conditionals and loops.
3. Use functions for structuring Python programs.
4. Represent compound data using Python lists, tuples, dictionaries.
5. Read and write data from/to files in Python.

Chapter	Name of the topic	Hours
01	Running Code in the Interactive Shell, Input, Processing and Output, Editing, Saving and Running a Script	1
02	Values and Data Types, Variables, Keywords, String Literals, Escape Sequences, Operators and Operands, Expressions and Statements	3
03	Arithmetic, Relational Operators and Comparison Operators, Python Assignment Operators Short hand Assignment Operators, Logical Operators or Bitwise Operators	2
04	String operations and indices Basic String Operations -- String Functions, Methods, Delete a string , String Multiplication and concatenation, String Formatting Operator, Python String replace() Method, Changing upper and lower case strings, Using “join” function for the string, Reversing String, Split Strings	2
05	If Statement, If-Elif statements, For loop, While Statement, Infinite loops, Break and Continue Statements.	2
06	List indices, Traversing a list, List operations, slices and methods - Map, filter and reduce, Deleting elements, Lists and strings, Understanding and using Ranges, More About Ranges, Creating nested tuple Using tuples as keys in dictionaries, Deleting	2

	Tuples Slicing of Tuple	
07	Python Set Operations Union of sets, Python Frozen set, Python Dictionary Methods, Copying dictionary and Updating Dictionary, Delete Keys from the dictionary, Dictionary items() Method, Sorting the Dictionary Python Dictionary in-built Functions, Dictionary len() Method, Variable Types Python List cmp() Method, Dictionary Str(dict)	2
08	Calling Value, Returning Functions, Calling Non-Value-Returning Functions, Parameter Passing, Keyword Arguments in Python, Default Arguments in Python, Nested Functions, Passing functions to function.	2
09	Constructor --Creating Classes and Objects, Inheritance, Overloading and Over Riding examples, Accessing attributes , Abstract classes and Interfaces, Abstract Methods and Abstract class, Interface in Python - Abstract classes and Interfaces	2
10	Handling an exception • try….except…else • try-finally clause, Argument of an Exception, Python Standard Exceptions, Raising an exceptions - User-Defined Exceptions	2
11	Regular Expression Syntax, Regular Expression Patterns Literal characters, Repetition Cases, Example of w+ and ^ Expression, Example of \s expression in re.split function Using regular expression methods, Using re.match(), Finding Pattern in Text (re.search()), Using re.findall for text Python Flags, Methods of Regular Expressions	2
12	Turtle Graphics, Turtle attributes, Modular Design: Modules, Top-Down Design, Python Modules, Text Files: Opening, reading and writing text files	2
13	Numpy: Introduction to numpy, Creating arrays, Indexing Arrays - Array Transposition, Universal Array Function, Array Processing, Array Input and Output, Pandas: - Series in pandas, Index objects, Reindex Drop Entry, Selecting Entries, Data Alignment, Rank and Sort, Summary Statics, Index Hierarchy, Matplotlib: Introduction to Matplotlib, Data Visualization, Python for Data Visualization	2

References:

1. M. Lutz, Learning Python Powerful Object Oriented Programming, O'reilly Media, 2018, 5th Edition.
2. T. A. Budd, Exploring Python, Tata MCGraw Hill Education Private Limited, 2011, 1st Edition.
3. A.Downey, J. Elkner, C. Meyers, How to think like a computer scientist: learning with Python, 2012.

Relationship of CO with PO mapping:

CO	PO									
	1	2	3	4	5	6	7	8	9	10
Python Programming Lab (MS-AM192(LAB))										
CO1: To write, test, and debug simple Python programs.	S	S	S	S	S	S	S	M	M	S
CO2: To implement Python programs with conditionals and loops.	S	M	S	S	S	M	M	L	L	S
CO3: Use functions for structuring Python programs.	S	M	S	S	S	M	M	M	M	S
CO4: Represent compound data using Python lists, tuples, dictionaries.	S	S	S	S	S	S	S	M	M	S
CO5: Read and write data from/to files in Python.	S	M	S	S	S	M	M	M	M	S

S- Strong; M-Medium; L-Low

Maulana Abul Kalam Azad University of Technology, West Bengal
Course: M.Sc in Applied Mathematics,
Effective from Academic Session: 2021-22
Duration: 2 Years (4 semesters); Level: Post graduation; Type: Degree

Semester-2:

Differential Equations with Boundary Value Problems	Course Code: MS-AM201 4 Credits, 100 marks

Course Objectives:

1. To identify the type of a given differential equation and select and apply the appropriate analytical technique for finding the solution of first order and selected higher order ordinary differential equation.
2. To create and analyze mathematical models using higher order differential equations to solve application problems such as harmonic oscillator and circuits.
3. To determine fundamental solutions and independence using the Wronskian.
4. Able to find Series solutions, Laplace transform, Linear systems of ordinary differential equations.

Module 1: General introduction and review of basic concepts: (3L)
Review of ODE, First order & higher order ODE, Linear & Non-Linear ODE, The solution procedure of ODE. Complete solution, Particular integral for exact solution, Some application.

Module 2: Initial & Boundary Value Problem (8L)
Solution of Differential Equations- Initial value problems for linear equations with constant coefficients, Two-point boundary value problem for a linear equation with constant coefficients, Linear differential equation with variable coefficients, Simultaneous differential equations with constant coefficients, Stability analysis of differential equation, Equilibrium solution & trajectory, Phase plane.

Existence and uniqueness theorem, General Theory of homogeneous and non- homogeneous ODE, Wronskian, Abel identity, Adjoint and self-adjoint equation, Strum-Liouville equation and boundary value problem, Green function, Solution of Second order ODE in complex domain.

Module 3: Bessels & Legendre Equation for ODE (5L)
Solution of Bessel and Legendre equation, Bessel's functions, Generating function, recurrence relation, representation for the indices, Bessel's integral formula, Bessel's functions of second kind, Legendre polynomials, generating function, Recurrence relation, Rodrigue's formula, orthogonal property, Solution of diffusion and wave equation in one dimension and Laplace equation in two dimensions.

Module 4: Partial Differential Equation: (3L)
Lagrange's method of solving first order PDE, Cauchy-Kwalewski Theorem (Statement only), Cauchy problem for first order PDE, Classification of second order PDEs, General solutions of higher order PDEs with constant coefficients.

Module 5: Application of PDE: (4L)
Solution of Laplace equation, heat and wave equation by separation of variables method (upto two-dimensional cases), Solution of Partial Differential Equations by means of Fourier Transforms. First

order and second order Laplace and Diffusion equations.

References:

1. M.Birkhoff and G.C.Rota, Ordinary Differential Equation
2. E.L.Ince, Ordinary Differential Equation
3. G.F.Simmons, Differential Equation
4. Ross, Ordinary Differential Equation
5. E.E.Coddington & N.Levinson, Theory of Ordinary Differential Equation
6. I.N.Sneddon, Elements of Partial Differential Equation
7. E.Epstein, Partial Differential Equation

Relationship of CO with PO mapping:

CO	**PO**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Differential Equations with Boundary Value Problems (MS-AM201)										
CO1: To identify the type of a given differential equation and select and apply the appropriate analytical technique for finding the solution of first order and selected higher order ordinary differential equation.	S	S	S	M	S	S	M	M	M	L
CO2: To create and analyze mathematical models using higher order differential equations to solve application problems such as harmonic oscillator and circuits.	S	S	S	S	S	M	S	M	L	M
CO3: To determine fundamental solutions and independence using the Wronskian.	S	S	M	S	L	S	M	S	M	L
CO4: Able to find Series solutions, Laplace transform, Linear systems of ordinary differential equations.	S	M	L	S	M	M	M	S	M	L

S- Strong; M-Medium; L-Low

Advanced Numerical Analysis and CFD	**Course Code: MS-AM202** **4 Credits, 100 marks**

Course Objectives:

1. To learn various methods for the system of linear equations and eigenvalue problem.
2. To find the numerical solution of initial value and boundary value problems.
3. To get basic knowledge of governing equation for fluid flow (Navier-Stokes equations) and heat transfer (Energy equation).
4. To introduce basics of computational fluid dynamics via finite difference methods for incompressible viscous fluid flows.
5. To provide an introduction of finite volume method.

Module 1: System of linear equations and eigenvalue problem: 12L

Solving system of linear algebraic equations: Gaussian operational count for inversion of a matrix, Tri-diagonal systems, Thomas algorithm, General iterative method: Jacobi and Gauss Seidel method. Necessary and sufficient conditions for convergence. Speed of convergence. Relaxation method. S.O.R. and S.U.R. methods. Eigenvalue problem: Power method, Inverse Power method of finding eigenvalues and eigenvectors of Matrices.

Module 2: Numerical Solution of Initial Value and Boundary Value Problems: 12L

First Order Equation: One step methods- 2nd and 4th orders Runge-Kutta methods, Multistep predictor-corrector methods – Adams-Bashforth method, Adams-Moulton method, Milne's method, Convergence and stability. Higher Order Equations: 2nd and 4th orders Runge-Kutta methods, Absolute stability of predictor-corrector methods; Stiff differential equations. Two-points Boundary Value Problems for ODE: Shooting method, the method of bisection, the Newton-Raphson method.

Module 3: Basic equations of fluid dynamics: 10L

General form of a conservation law; Equation of mass conservation; Conservation law of momentum; Conservation equation of energy. Incompressible form of the Navier-Stokes equations, Physical interpretation of each term, Boundary Conditions, Reynolds number, Nondimensionalization of Navier-Stokes equations and Energy equations, Importance of Reynolds number to Navier-Stokes Equation, Exact Solution of Navier-Stokes Equation (Couette-Poisseuille flow).

Module 4: Incompressible Viscous Flows via Finite Difference Methods: **12L**

Preliminaries of computational fluid dynamics: Size of Computational Domain, Consideration of uniform and non-uniform Grids, Variable arrangement (Cell center / Colocated arrangement or Staggered Gird). Discretisation: Space discretisation (Simple and general methods based on Taylor's series for first, second, and fourth order accuracy, and hence Accuracy of the Discretisation Process), Higher-Order vs Low-Order Formulae, and Time discretization (Explicit Algorithm: forward time centered space (FTCS) scheme, Richardson, DuFort- Frankel, and Implicit Algorithm: Crank-Nicolson and alternating-direction implicit (ADI) method). Implementation of Boundary Conditions: Dirichlet, Neumann and Robin boundary conditions.

Module 5: Finite Volume Method: 10L

Equations with First order Derivatives Only, with second order Derivatives, and its application to Steady one-dimensional heat conduction, Steady One-Dimensional Convection and Diffusion.

References:

1. C.F. Gerald, and P.O. Wheatly: Applied Numerical Analysis, Addison-Wesley Publishing, 2002
2. J. D. Anderson Jr., Computational Fluid Dynamics (The Basics with Applications), McGraw-Hill Series in Mechanical Engineering
3. C. A. J Fletcher, Computational Technique for Fluid Dynamics, Springer
4. F. M. White, Fluid Mechanics (4th Edition), WCB McGraw-Hill.

Relationship of CO with PO mapping:

CO	**PO**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Advanced Numerical Analysis and CFD (MS-AM202)										
CO1: To learn various methods for the system of linear equations and eigenvalue problem.	S	M	S	M	S	S	M	M	M	L
CO2: To find the numerical solution of initial value and boundary value problems.	S	S	M	S	S	M	S	M	L	M
CO3: To get basic knowledge of governing equation for fluid flow (Navier-Stokes equations) and heat transfer (Energy equation).	S	S	S	S	L	S	M	S	M	L
CO4: To introduce basics of computational fluid dynamics via finite difference methods for incompressible viscous fluid flows.	S	S	L	S	M	M	M	S	M	L
CO5: To provide an introduction of finite volume method.	S	S	M	S	L	M	S	M	M	M

S- Strong; M-Medium; L-Low

Continuum Mechanics and Introduction to Fluid Dynamics	**Course Code: MS-AM203** **4 Credits, 100 marks**

Course Objectives:

1. To familiarize with the properties of fluids and the applications of fluid mechanics.
2. To formulate and analyze problems related to calculation of forces in fluid structure interaction.
3. To understand the concept of fluid measurement, types of flows and dimensional analysis.
4. Demonstrate knowledge of the physical meanings, principles, and mathematics of continuous media represented as solids, liquids, and gases.
5. Formulate and solve simplified problems using the language and methods of continuum mechanics. Be able to combine distinct concepts and to introduce reasonable assumptions when faced with ambiguity in data or instructions.

Module 1 12L

Principles of continuum mechanics, Forces in a continuum. The idea of internal stress. Stress tensor. Equations of equilibrium. Symmetry of stress tensor. Stress transformation laws. Principal stresses and principal axes of stresses. Stress invariants. Stress quadric of Cauchy. Shearing stresses.

Module 2 10L

Deformation. Strain tensor. Finite strain components in rectangular Cartesian coordinates. Infinitesimal strain components. Geometrical interpretation of infinitesimal strain components. Principal strain and principal axes of strain. Strain invariants. The compatibility conditions.

Module 3 8L

Constitutive equations. Inviscid fluid. Circulation. Kelvins energy theorem. Constitutive equations for elastic material and viscous fluid. Navier-Stokes equation of motion.

Module 4 **10L**

Motion of deformable bodies. Lagrangian and Eulerian methods to the study of motion of a continua. Material derivative of a volume integral. Equation of continuity. Equation of motion. Equation of angular momentum. Equation of Energy.

Module 5 **12L**

Boundary conditions and boundary surface, stream lines and paths of particles. Irrotational and rotational flows, velocity potential. Bernoulli's equation, Theory of irrotational motion, flow and circulation. Permanence of irrotational motion. Milne-Thomson circle theorem, Theorem of Blasius. Motion of circular and elliptic cylinders.

References:

1. Y.C. Fung-A first course in continuum Mechanics
2. W. Prager-Mechanics of Continuous media
3. R. N. Chatterjee – Contunuum Mechanics
4. AS Ramsay-Hydrodynamics
5. L.M.Milne Thomson- Theoretical Hydrodynamics
6. G. K. Batchelor – Fluid Dynamics (Cambridge University Press)

Relationship of CO with PO mapping:

CO	**PO**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Continuum Mechanics and Introduction to Fluid Dynamics (MS-AM203)										
CO1: To familiarize with the properties of fluids and the applications of fluid mechanics.	S	S	S	M	S	S	S	M	M	L
CO2: To formulate and analyze problems related to calculation of forces in fluid structure interaction.	S	S	M	S	S	M	S	M	L	M
CO3: To understand the concept of fluid measurement, types of flows and dimensional analysis.	S	S	M	S	M	S	M	S	S	L
CO4: Demonstrate knowledge of the physical meanings, principles, and mathematics of continuous media represented as solids, liquids, and gases.	S	S	S	S	M	M	M	S	M	L
CO5: Formulate and solve simplified problems using the language and methods of continuum mechanics. Be able to combine distinct concepts and to introduce	S	S	S	L	M	S	L	S	M	M

reasonable assumptions when faced with ambiguity in data or instructions.										

S- Strong; M-Medium; L-Low

Abstract Algebra and Applications	**Course Code: MS-AM204** **4 Credits, 100 marks**

Course Objectives:

1. To introduce basic structures of algebra like groups, rings and fields which are the main pillars of modern mathematics.
2. To understand the concepts of homomorphism and isomorphism between groups.
3. To apply class equation and Sylow theorems to solve different problems.
4. To explore the properties of rings, sub-rings, ideals including integral domain, principle ideal domain, Euclidean ring and Euclidean domain.
5. To understand the concepts of homomorphism and isomorphism between rings.
6. To understand and apply field and field extensions for applications.

Module 1 **12L**

Quotient Groups, Normal sub groups and correspondence theorem for groups Homomorphism, Isomorphism of groups, First and second isomorphism theorems, automorphisms and automorphism group, Inner automorphisms, groups of order 4 and 6. The groups D_4 and Q_8.

Ring, commutative rings with identity, Prime & irreducible elements, division ring, Quaternions, idempotent element, Boolean ring, ideals, Prime ideal, maximal ideal, Isomorphism theorems, relation between Prime and maximal ideal.

Module 2 **12L**

Conjugacy Classes, Sylow's theorems, Sylow p-subgroups, Direct product of groups, Simple groups and solvable groups, nilpotent groups, simplicity of alternating groups, Normal and subnormal series, composition series, Jordan-Holder Theorem. Semi-direct products. Free groups, free abelian groups, External direct product of groups, properties of external direct products, internal direct products, fundamental theorem of finite abelian groups and applications.

A collection of algebraic structures; The Euclidean algorithm (for polynomials); Error correcting codes; Groups and codes.

Module 3 **12L**

Rings, Rings of fractions, Chinese Remainder Theorem for pairwise comaximal ideals. Euclidean Domains, Principal Ideal Domains and Unique Factorizations Domains. Polynomial rings, rings of formal power series, embedding theorems, field of fractions.

Module 4 **12L**

Fields, Characteristic and prime subfields, Field extensions, Finite, algebraic and finitely generated field extensions, Classical ruler and compass constructions, Splitting fields and normal extensions, algebraic closures. Finite fields, Cyclotomic fields, Separable and inseparable extensions.

Module 5 **12L**

Galois groups, Fundamental Theorem of Galois Theory, Composite extensions, Examples (including cyclotomic extensions and extensions of finite fields). Norm, trace and discriminant. Solvability by radicals, Galois' Theorem on solvability, Cyclic extensions, Abelian extensions, Polynomials with Galois groups Sn. Transcendental extension. Applications – Cyclic codes, BCH code.

Reference Books:

1. I.N. Herstein, Topics in Algebra, Wiley & Sons publications 1975
2. D.S. Dummit and R. M. Foote, Abstract Algebra, 2nd Ed., John Wiley, 2002.
3. Dummit, D. S. & Foote, R. M., Abstract Algebra, 3rd edition (John Wiley & Sons, Indian reprint, New Delhi, 2011)
4. Gallian, J. A., Contemporary Abstract Algebra, 4th edition (Narosa Publishing house, New Delhi, 2009)
5. Jacobson, N. (2002) Basic Algebra I (3rd edition), Hindustan Publishing Corporation, New Delhi.
6. D. S. Malik, J. N. Moderson, M. K. Sen, Fundamentals of Abstract Algebra, McGraw-Hill
7. M. Artin, Algebra, Prentice Hall of India, 1994.

Relationship of CO with PO mapping:

CO	**PO**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Abstract Algebra and Applications (MS-AM204)										
CO1: To introduce basic structures of algebra like groups, rings and fields which are the main pillars of modern mathematics.	S	S	S	M	S	S	S	M	M	L
CO2: To understand the concepts of homomorphism and isomorphism between groups.	S	S	S	S	S	M	S	M	L	M
CO3: To apply class equation and Sylow theorems to solve different problems.	S	S	S	S	**M**	S	M	S	S	L
CO4: To explore the properties of rings, sub-rings, ideals including integral domain, principle ideal domain, Euclidean ring and Euclidean domain.	S	S	M	S	M	L	M	S	M	L
CO5: To understand the concepts of homomorphism and isomorphism between rings.	S	S	S	M	S	S	M	S	L	M
CO6: To understand and apply field and field extensions for applications.	S	S	M	S	S	S	M	L	M	M

S- Strong; M-Medium; L-Low

Research Methodology and IPR	**Course Code: MS-AM205** **2 Credits, 100 marks**

Course Objectives:

1. To gain knowledge for an overview of the research methodology and ability to explore the technique of defining a research problem.
2. To learn the functions of the literature review in research and ability for carrying out a literature search, its review, developing theoretical and conceptual frameworks and writing a review.
3. To investigate various research designs and their characteristics and o explain the details of sampling designs, measurement and scaling techniques along with different methods of data collections.
4. To gain knowledge of various forms of the intellectual property, its relevance and business impact in the changing scenario of global business environment.

Module-1 **(4L)**

Meaning of research problem, Sources of research problem, Criteria and characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, Data collection, Analysis, Interpretation, Necessary instrumentations.

Module-2 **(3L)**

Effective literature studies, Approaches, Analysis. Plagiarism and research ethics.

Module-3 **(4L)**

Effective technical writing, how to write report, Paper. Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee.

Module-4 **(3L)**

Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

Module-5 **(3L)**

Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications.

Module-6 **(3L)**

New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

References:

1. S. Melville and W. Goddard, Research methodology: an introduction for science & engineering students.

2. W. Goddard and S. Melville, Research Methodology: An Introduction.
3. R. Kumar, 2nd Edition, Research Methodology: A Step by Step Guide for beginners.
4. Halbert, Resisting Intellectual Property, Taylor & Francis Ltd, 2007.
5. Mayall, Industrial Design, McGraw Hill, 1992.
6. Niebel, Product Design, McGraw Hill, 1974.
7. Asimov, Introduction to Design, Prentice Hall, 1962.
8. R. P. Merges, Peter S. Menell, Mark A. Lemley, Intellectual Property in New Technological Age, 2016.
9. T. Ramappa, Intellectual Property Rights Under WTO, S. Chand, 2008.

Relationship of CO with PO mapping:

CO	**PO**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Research Methodology and IPR (MS-AM205)										
CO1: To gain knowledge for an overview of the research methodology and ability to explore the technique of defining a research problem.	S	S	M	M	S	S	M	M	M	M
CO2: To learn the functions of the literature review in research and ability for carrying out a literature search, its review, developing theoretical and conceptual frameworks and writing a review.	S	S	S	M	S	M	S	M	M	M
CO3: To investigate various research designs and their characteristics and o explain the details of sampling designs, measurement and scaling techniques along with different methods of data collections.	S	S	M	S	M	M	M	S	M	L
CO4: To gain knowledge of various forms of the intellectual property, its relevance and business impact in the changing scenario of global business environment.	S	M	M	S	M	M	M	S	M	L

S- Strong; M-Medium; L-Low

Elective- I (DSE):

Number Theory and Cryptography	**Course Code: MS-AM206A** **4 Credit, 100 marks**

Course Outcome:

1. Students are able to learn methods and techniques used in number theory.
2. After the completion of the course, they can solve systems of Diophantine equations using Chinese Remainder theorem & the Euclidean algorithm.
3. Students can understand the most common type of cryptographic algorithm, public key infrastructures.
4. Students can understand the basics of modular arithmetic.
5. Students can learn fundamentals of cryptography and its application to network security and understand vulnerability analysis of network security.
6. Students can acquire background knowledge on hash functions; authentication etc.

Module 1: **10L**

Basic Number Theory: The Well ordering principle, The Division algorithm, Prime numbers, GCD, Fermat Numbers, Perfect Numbers, Mersenne Numbers. Primitive roots, the group of units $\mathbb{Z}_n^*$, the existence of primitive roots, Applications of primitive roots, the algebraic structure of $\mathbb{Z}_n^*$.

Module 2: **10L**

Quadratic residues and non quadratic residues, Quadratic Congruence, Legendre symbol, Proof of the law of quadratic reciprocity, Jacobi symbols. Arithmetic functions, definitions and examples, the Möbius Inversion formula, Properties of Möbius function. Sum of two squares, the sum of three squares and the sum of four squares.

Module 3: **10L**

Faster integer multiplication, Extended Euclid's algorithm, Quadratic residues, Chinese Remainder theorem, Fast modular exponentiation, Choosing a random group element, Finding a generator of a cyclic group, Finding square roots modulo a prime p, Polynomial arithmetic, arithmetic in finite fields, Computing order of an element, Computing primitive roots, fast evaluation of polynomials at multiple points, primality testing, Miller-Rabin Test, Generating random primes, primality certificates, Algorithms for factorizing, algorithm for computing discrete logarithms.

Module 4: **10L**

Cryptography: Concepts & Techniques- Introduction, Plaintext & Cipher text, Substitution Techniques, Transposition Techniques, Encryption & Decryption, Symmetric & Asymmetric key Cryptography, Key Range & Key Size Symmetric key algorithm, Overview of Symmetric Key Cryptography, DES (Data Encryption Standard) algorithm, IDEA (International Data Encryption Algorithm) algorithm, RC5(Rivest Cipher 5) algorithm.

Asymmetric key algorithm, Digital Signature and RSA - Introduction, Overview of Asymmetric key Cryptography, RSA algorithm, Symmetric & Asymmetric key Cryptography together, Digital Signature, Basic concepts of Message Digest and Hash Function (Algorithms on Message Digest and Hash function not required) Internet Security Protocols, User Authentication - Basic Concepts, SSL protocol, Authentication Basics, Password, Authentication Token, Certificate based Authentication, Biometric Authentication.

References:

1. J. Hoffstein, J.. Pipher, J.H.Silverman; An Introduction to Mathematical Cryptography; Springer.
2. J. Katz, Y. Lindell; Introduction to Modern Cryptography; Chapman & Hall/CRC.
3. N. Koblitz; A course in number theory and cryptography; Springer-Verlag, 2nd edition.
4. K. H. Rosen; Elementary Number Theory & Its Applications; AT&T Bell Laboratories, AdditionWesley Publishing Company, 3rd Edition.
5. K. Ireland & M. Rosen; A Classical Introduction to Modern Number Theory, 2nd edition; Springer-verlag. 42.

Relationship of CO with PO mapping:

CO	PO									
	1	2	3	4	5	6	7	8	9	10
Number Theory and Cryptography (MS-AM206A)										
CO1: Students are able to learn methods and techniques used in number theory.	S	S	S	S	S	S	M	M	M	M
CO2: After the completion of the course, they can solve systems of Diophantine equations using Chinese Remainder theorem & the Euclidean algorithm.	S	S	S	S	S	M	S	M	M	M
CO3: Students can understand the most common type of cryptographic algorithm, public key infrastructures.	S	S	S	S	M	M	M	S	M	L
CO4: Students can understand the basics of modular arithmetic.	S	S	S	S	M	M	M	S	M	L
CO5: Students can learn fundamentals of cryptography and its application to network security and understand vulnerability analysis of network security.	S	S	S	M	M	S	S	S	M	L
CO6: Students can acquire background knowledge on hash functions; authentication etc.	S	M	S	S	S	S	S	M	S	L

S- Strong; M-Medium; L-Low

Operation Research: Queuing Theory and Game Theory	Course Code: MS-AM206B 4 Credits, 100 marks

Course Objectives:

1. Knowledge of game theory would help students to understand and analyze real life situations such as market behavior or voting in elections.
2. Analytical concepts of Game theory which might be useful should they decide to pursue social sciences, engineering, sciences or managerial higher studies.
3. To understand the significance of advanced queueing models.

4. To understand the concept of queueing models and apply in engineering.

Module 1: **Game theory** **15 L**

Introduction to game. Strategic game: examples, Strategic games: examples Nash equilibrium: concept and examples best response functions Dominated Actions Symmetric games and symmetric equilibria, Strategic games with randomization Mixed strategy Nash equilibrium: concept and examples Dominated Actions, Concept of Saddle point, Solvable game and non-solvable game.

Module 2: Queueing Theory 10L

Markovian queues – Birth and death processes – Single and multiple server queueing models – Little‘s formula – Queues with finite waiting rooms – Queues with impatient customers: Balking and reneging.

Module 3: Queuing Theory **10L**

Finite source models – Different components of a queue, M/G/1 queue, M/M/1 queue. Expression for Expected number of customers in system (Ls), Expected Number of customers in queue (Lq), Expected waiting time in the system (Ws), Expected waiting time in the queue (Wq), Expected number of busy servers

Reference Books:

1. H. A. Taha, Operations Research, Pearson,2008
2. R. Bonson, Scuthman’s outline of operations research, MacgrawHill,1997
3. N. H. Shah & R. M. Gor, Operations Research, PHI Learning Private Limited,2010

Relationship of CO with PO mapping:

CO	**PO**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Operation Research: Queuing Theory and Game Theory (MS-AM206B)										
CO1: Knowledge of game theory would help students to understand and analyze real life situations such as market behavior or voting in elections.	S	S	S	S	S	S	M	M	M	M
CO2: Analytical concepts of Game theory which might be useful should they decide to pursue social sciences, engineering, sciences or managerial higher studies.	S	S	M	S	L	M	S	M	M	M
CO3: To understand the significance of advanced queueing models.	S	S	S	S	M	S	M	S	M	L
CO4: To understand the concept of queueing models and apply in engineering.	S	S	M	S	M	S	M	S	M	L

S- Strong; M-Medium; L-Low

Maulana Abul Kalam Azad University of Technology, West Bengal
Course: M.Sc in Applied Mathematics,
Effective from Academic Session: 2021-22
Duration: 2 Years (4 semesters); Level: Post graduation; Type: Degree

Fuzzy Sets and Applications	**Course Code: MS-AM206C** **4 Credits, 100 marks**

Course Objectives:

1. Understand basic knowledge of the fuzzy sets, operations and their properties.
2. Understand the fundamental concepts of Fuzzy functions and Fuzzy logic.
3. Apply the concepts of Fuzzy sets in image processing, Pattern reorganization and Decision making.
4. To analyze and visualization of uncertain problem associated with real life applications.

Module 1 **12L**

Basic concepts of fuzzy set, t-norm, t-conorms, membership function, α-cut, Algebra of fuzzy sets , distance between fuzzy sets, fuzzy relation. Fuzzy numbers , Arithmetic operations of fuzzy numbers , Extension principle, Interval arithmetic, Defuzzification.

Module 2 **10L**

Fuzzy valued functions , fuzzy equations, fuzzy inequalities , system of fuzzy . linear equations , maximum and minimum of fuzzy functions, fuzzy differential equation.

Module 3 **10L**

Classical Logic – Multi-valued Logics – Fuzzy Propositions – Fuzzy Quantifiers – Linguistic hedges – Inference from conditional Fuzzy proposition.

Module4 **12L**

Fuzzy sets in Decision making , Optimization in Fuzzy environment, Fuzzy set application in image processing , Fuzzy set application in Pattern reorganization.

References:

1. G. J. Klir and B. Yuan, Fuzzy sets and Fuzzy logic Theory and applications , Prentice Hall of India, New Delhi.
2. D. Bubois and H. Prade , Fuzzy sets and systems , Academic Press
3. J. J Buckley , Esfandiar Eslami ,An Introduction to Fuzzy logic and Fuzzy sets (Springer)
4. H.J.Zimmernman , Fuzzy set theory and application (Allied Publication in Association with KLUWER).

Relationship of CO with PO mapping:

CO	**PO**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Fuzzy Sets and Applications (MS-AM206C)										
CO1: Understand basic knowledge of the fuzzy sets, operations and their properties.	S	S	S	M	S	S	M	M	M	M
CO2: Understand the fundamental concepts of Fuzzy functions and Fuzzy logic.	S	S	M	M	L	M	S	M	M	M
CO3: Apply the concepts of Fuzzy sets in image processing, Pattern reorganization and Decision making.	S	S	M	S	M	S	M	S	M	L

CO4: To analyze and visualization of uncertain problem associated with real life applications.	S	S	S	S	M	S	M	S	M	L

S- Strong; M-Medium; L-Low

Differential Geometry	**Course Code: MS-AM206D** **4 Credits, 100 marks**

Course Objectives:

1. Introducing the concepts: Regular curves, arc length, and natural parametrization.
2. Introducing the concepts: Simple surfaces, tangent vectors and tangent spaces, and first and second fundamental forms.
3. Introducing the concepts: Normal and geodesic curvatures, Weingarten map, principal curvatures, Gaussian and mean curvatures.
4. Introducing the concepts: Equations of Gauss and geodesics.

Module1: 10L

Local curve theory: Serret-Frenet formulation, fundamental existence theorem of space curves. Plane curves and their global theory: Rotation index, convex curves, isoperimetric inequality, Four vertex theorem.

Module2: 12L

Local surface theory: First fundamental form and arc length, normal curvature, geodesic curvature and Gauss formulae, Geodesics, parallel vector fields along a curve and parallelism, the second fundamental form and the Weingarten map, principal, Gaussian, mean and normal curvatures, Riemannian curvature and Gauss's theorem Egregium, isometries and fundamental theorem of surfaces.

Module3: 6L

Global theory of surfaces: Geodesic coordinate patches, Gauss-Bonnet formula and Euler characteristic, index of a vector field, surfaces of constant curvature.

Module4: 10L

Elements of Riemannian geometry: Concept of manifold, tensors (algebraic and analytic), covariant differentiation, symmetric properties of curvature tensor, notion of affine connection, Christoffel symbols; Riemannian metric and its associated affine connection, geodesic and normal coordinates.

References:

1. M. P. Do Carmo: Riemannian Geometry, Birkhauser
2. William M. Boothby: An Introduction to Differentiable Manifolds and Riemannian Geometry, Academic Press
3. Kumaresan: Differential geometry and Lie groups, TRIM Series

Relationship of CO with PO mapping:

CO	PO									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Differential Geometry (MS-AM206D)										
CO1: Introducing the concepts: Regular curves, arc length, and natural parametrization.	S	S	M	M	S	S	M	M	L	M
CO2: Introducing the concepts: Simple surfaces, tangent vectors and tangent spaces, and first and second fundamental forms.	S	S	S	M	L	M	S	M	L	M
CO3: Introducing the concepts: Normal and geodesic curvatures, Weingarten map, principal curvatures, Gaussian and mean curvatures.	S	S	S	S	M	S	M	S	M	M
CO4: Introducing the concepts: Equations of Gauss and geodesics.	S	S	S	S	M	S	M	S	L	L

S- Strong; M-Medium; L-Low

Theory of Computation and Finite Machine Analysis	**Course Code: MS-AM206E** **4 Credits, 100 marks**

Course Objectives:

1.To Examine the properties of formal language and automata, their equivalence and conversion techniques.
2. To understand the concept of Context Free Grammars and Pushdown Automata.
3.To give an overview of the theoretical foundations of computer science from the perspective of formal languages.
4. To illustrate finite state machines to solve problems in computing
5. To explain the hierarchy of problems arising in the computer sciences.
6. To familiarize Regular grammars, context frees grammar.

Module 1: **7L**

Fundamentals: Basic definition of sequential circuit, block diagram, mathematical representation, concept of transition table and transition diagram (Relating of Automata concept to sequential circuit concept) Design of sequence detector, Introduction to finite state model.

Finite state machine: Definitions, capability & state equivalent, kth- equivalent concept, Merger graph, Merger table, Compatibility graph, Finite memory definiteness, testing table & testing graph. Deterministic finite automaton and non-deterministic finite automaton. Transition diagrams and Language recognizers.

Module 2: **10L**

Finite Automata (FA): Introduction, Deterministic Finite Automata (DFA) -Formal definition, simpler notations (state transition diagram, transition table), language of a DFA. Nondeterministic Finite Automata (NFA)- Definition of NFA, language of an NFA, Equivalence of Deterministic and Nondeterministic Finite Automata, Applications of Finite Automata, Finite Automata with Epsilon Transitions, Eliminating Epsilon transitions, Minimization of Deterministic Finite Automata, Finite automata with output (Moore and Mealy machines) and Inter conversion.

Module 3: **12L**

Regular Expressions (RE): Introduction, Identities of Regular Expressions, Finite Automata and Regular Expressions- Converting from DFA's to Regular Expressions, Converting Regular Expressions to Automata, applications of Regular Expressions. Regular grammars and FA, FA for regular grammar, Regular grammar for FA. Proving languages to be non-regular -Pumping lemma, applications, Closure properties of regular languages. Derivation Trees, Sentential Forms, Rightmost and Leftmost derivations of Strings. Ambiguity in CFG's, Minimization of CFG's, CNF, GNF, Pumping Lemma for CFL's, Enumeration of Properties of CFL (Proof's omitted).

Module 4: **6L**

Recursive and Recursively Enumerable Languages (REL): Properties of recursive and recursively enumerable languages, Universal Turing machine, The Halting problem, Undecidable problems about TMs. Context sensitive language and linear bounded automata (LBA), Chomsky hierarchy, Decidability, Post's correspondence problem (PCP), undecidability of PCP.

Module 5: 6L

Turing machines: Definitions and ExamplesCombining turing machines, Multitape TM, Universal Turing Machines – Halting Problem of Turing Machines – Church's Thesis.

References:

1. V Sarthi, Theory of Computation
2. C. K. Nagpal, Formal Languages and automata theory.
3. K. L. P Mishra, N. Chandrashekaran (2003), Theory of Computer Science-Automata Languages and Computation, 2nd edition, Prentice Hall of India, India.
4. J. E. Hopcroft, R. Motwani, J. D. Ullman (2007), Introduction to Automata Theory
5. Languages andComputation, 3rdedition, Pearson Education, India.

Relationship of CO with PO mapping:

CO	**PO**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Theory of Computation and Finite Machine Analysis (MS-AM206E)										
CO1: To Examine the properties of formal language and automata, their equivalence and conversion techniques.	S	S	S	M	S	S	M	M	L	M
CO2: To understand the concept of Context Free Grammars and Pushdown Automata.	S	S	S	S	L	M	S	M	L	L
CO3: To give an overview of the theoretical foundations of computer science from the perspective of formal languages.	S	S	S	S	M	S	M	S	M	L
CO4: To illustrate finite state machines to solve problems in computing.	S	S	S	S	M	S	M	S	L	L
CO5: To explain the hierarchy of problems arising in the computer sciences.	S	S	M	M	S	S	L	M	M	L
CO6: To familiarize Regular grammars, context frees grammar.	S	S	S	L	M	M	L	S	M	L

S- Strong; M-Medium; L-Low

Advanced Numerical Analysis Lab	**Course Code: MS-AM291(LAB)** **2 Credits, 100 marks**

Course Objectives:

1. To understand analytical, developmental and technical principles that relate to Numerical Analysis.
2. Numerical Methods for solving Differential Equations, and Numerical Optimization, develop the academic abilities required to solve problems and applications in Numerical Analysis.
3. Numerical Optimization and critically assess relevant aspects of the industry.
4. To demonstrate an ability to initiate and sustain in-depth research in Numerical Analysis or Numerical Optimization.

Contents for numerical experiments in virtual flow laboratory through computer programming in FORTRAN, C-Language, MATLAB:

List of Practical Problems

1. Gauss-Jordon method.
2. Inverse of a matrix
3. S.O.R. / S.U.R. method
4. Relaxation method
5. Solution of one dimensional heat conduction equation by
   i) Explicit and
   ii) Crank-Nicolson implicit method.
6. Solution of Laplace equation.
7. Solution of Poisson equation.
8. Solution of one-dimensional wave equation.
9. Solution of ordinary differential and partial differential equation by weighted Residual method :
   a. Least square method.
   b. Galerkin method.
10. Solution of simple boundary value problem by
    a. Finite element and
    b. Boundary element method.
11. Solution of system of Non-linear equations by Newton's method.
12. Method of steepest descent.

References:

1. S.S.Sastry, Introductory methods of Numerical solutions, 4th Edition, Prentice Hall of India.
2. N.P. Bali Etal, A Text book on Engineering Mathematics, Laxmi pub. (p) Ltd, 2001.
3. Erwin kreyszig, Advanced Engineering Mathematics, John Wiley Publications, 1999.
4. R.K.Jain & S.R.K.Iyengar, Numerical Methods by, New Age International (P) Limited, 2008

Relationship of CO with PO mapping:

CO	**PO**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Advanced Numerical Analysis Lab (MS-AM291(LAB))										

CO1: To understand analytical, developmental and technical principles that relate to Numerical Analysis.	S	S	S	S	S	S	S	M	M	S
CO2: Numerical Methods for solving Differential Equations, and Numerical Optimization, develop the academic abilities required to solve problems and applications in Numerical Analysis.	S	M	S	S	S	M	M	L	L	S
CO3: Numerical Optimization and critically assess relevant aspects of the industry.	S	M	S	S	S	M	M	M	M	S
CO4: To demonstrate an ability to initiate and sustain in-depth research in Numerical Analysis or Numerical Optimization.	S	M	M	S	M	M	M	S	M	L

S- Strong; M-Medium; L-Low

Computational Fluid Dynamics Lab	**Course Code: MS-AM292(LAB)** **2 Credits, 100 marks**

Course Objectives:

1. To recognize the importance of CFD in Heat and Fluid flow.
2. To analyze forced convection heat transfer coefficient over regular bodies like sphere, cylinder.
3. To estimation of drag coefficient in circular pipe under turbulent flow and bent pipe.
4. To recognize how to handling moving boundaries and wall effects in motion of fluid.
5. To analyze how to handle power law fluids in CFD.

Contents for numerical experiments in virtual flow laboratory through computer programming in FORTRAN, C-Language, MATLAB:

1). Lab Component for Shooting Methods for boundary value problems
2). Lab Component for One dimensional heat conduction equation by forward time centered space (FTCS) scheme, Crank-Nicolson and alternating-direction implicit (ADI) method). Apply Thomas algorithm wherever applicable here. Compare root mean square value and approximate order of convergence for these methods by choosing different grid length and time step.
3). Solution of Couette, Poisseuille and Couette-Poisseuille flow using FTCS and Crank-Nicolson methods.
4). Lab Component for Laplace equation by Finite Volume Method.
5). Lab Component for Steady one-dimensional heat conduction by Finite Volume Method.
6) Turbulent flow in a circular pipe: generating the friction coefficient versus Reynolds number.
7) Calculation of forces over a bent pipe.
8) Calculation of flow and heat transfer in a lid driven cavity.
9) Wall effect on a sphere in a cylindrical tube.
10) Flow of Newtonian and non Newtonian fluids.

References:

1. C.Y. Chow and S. Biringen, An Introduction to Computational Fluid Mechanics, Wiley, 2011.
2. T. K. Bose, Computational Fluid Dynamics, Wiley Eastern Ltd., 1988.
3. C.A.J. Fletcher, Computational Techniques for Fluid Dynamics, Vol.II, Springer-Verlag, Berlin, 1991.

Relationship of CO with PO mapping:

CO	**PO**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Computational Fluid Dynamics Lab (MS-AM292(LAB))										
CO1: To recognize the importance of CFD in Heat and Fluid flow.	S	S	S	M	S	S	S	M	M	L
CO2: To analyze forced convection heat transfer coefficient over regular bodies like sphere, cylinder.	S	S	M	S	S	M	S	M	L	M
CO3: To estimation of drag coefficient in circular pipe under turbulent flow and bent pipe.	S	S	M	S	M	S	M	S	S	L
CO4: To recognize how to handling moving boundaries and wall effects in motion of fluid.	S	S	S	S	M	M	M	S	M	L
CO5: To analyze how to handle power law fluids in CFD.	S	S	S	L	M	S	L	S	M	M

S- Strong; M-Medium; L-Low

Semester-3:

Topology and Functional Analysis	**Course Code: MS-AM301** **4 Credits, 100 marks**

Course Objectives:
After completing the course, students will be able to

1. Impart the knowledge of topological and functional analysis methodologies.
2. Understand Open bases and open sub bases.
3. Learn the importance and characterization of compact space.
4. Learn Continuous linear transformations and the Hahn-Banach theorem.
5. Understand the Open Mapping Theorem and its applications.
6. Understand the characteristics of abstract analysis
7. Apply the knowledge of basic linear operator theory.

Module 1 **10L**

Topological spaces: Elementary concepts, Different kind of topologies, Bases and Sub-bases. Limit point of a set, Closed set, Kuratowski closure operator, Continuity, Convergence, Homeomorphism., First and Second countability, Separable spaces, Product Spaces, Quotient spaces.
Separation axioms T_0, T_1, T_2, T_3, T_4 in topological spaces, Regular spaces, Normal spaces, Completely Regular spaces, Tychonoff spaces.

Module 2 **10L**

Open cover, sub-cover, Countable open cover, Compact Space, Sequentially Compact Space, Lindelöff space, Finite intersection property, locally compact spaces, One-point and Stone-Check Compactification. Connectedness, Separated sets, Topological product of connected spaces, Totally disconnected spaces, Locally connected spaces. Arzela - Ascoli's theorem.

Module 3 **10L**

Linear spaces: Normed linear spaces, Linear topological spaces, Inner Product spaces, Banach spaces, Hilbert spaces, Fundamental theorems for Normed & Banach spaces, Open Mapping and Closed Graph Theorem, Banach-Steinhous theorem Orthogonality in Hilbert spaces and related theorems (Orthogonal Projection Theorem; Best Approximation; Generalized Fourier Series; Bessel's Inequality; Complete Orthonormal set; Perseval's Theorem).

Module 4 **5L**

Linear functionals: Dual spaces, reflexive property, Hahn-Banach extension theorem, Representation of linear functionals on Hilbert spaces (Riesz representation theorem), strong and weak convergences of a sequence of elements and of a sequence of functionals.

Module 5 **5L**

Linear operators: Linear operators in normed linear spaces, uniform and point wise convergence of operators; Closed linear operators, Adjoint operator, Self-adjoint operators; Unitary and Normal operators.

References:

1. G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, Singapore, 1963.
2. J.R. Munkres, Topology, A First Course, Prentice-Hall of India Pvt. Ltd., New Delhi, 2000.
3. J.L. Kelley, General Topology, Von Nostrand, New York, 1995.
4. E. Kreyszig, Introductory Functional Analysis with Applications, John Wiley & Sons, New York, 1978.
5. M. Reed and B. Simon, Functional Analysis, Academic Press, Inc., London, 1980.
6. Goffman and Pedric, First course in Functional Analysis, PHI, 2002.

Relationship of CO with PO mapping:

CO	PO									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Topology and Functional Analysis (MS-AM301)										
CO1: Impart the knowledge of topological and functional analysis methodologies.	S	S	S	S	M	S	S	S	S	S
CO2: Understand Open bases and open sub bases.	S	S	M	S	M	S	S	M	S	S
CO3: Learn the importance and characterization of compact space.	S	M	M	S	M	S	M	L	M	S

CO4: Learn Continuous linear transformations and the Hahn-Banach theorem.	S	S	M	S	M	S	S	M	S	S
CO5: Understand the Open Mapping Theorem and its applications.	S	M	M	S	M	S	M	M	,M	S
CO6: Understand the characteristics of abstract analysis	S	S	M	S	M	S	S	S	S	S
CO7: Apply the knowledge of basic linear operator theory.	S	S	S	S	M	S	S	S	M	S

S- Strong; M-Medium; L-Low

Data Science-1: Machine Learning	**Course Code: MS-AM302** **4 Credits, 100 marks**

Course Objectives:

1. To learn the concept of how to learn patterns and concepts from data
2. Understand applications of ML in various functional areas & industries.
3. To design and analyze various machine learning algorithms and techniques with a modern outlook focusing on recent advances.
4. To explore supervised and unsupervised learning paradigms of machine learning.
5. To understand how reinforcement and evolutionary algorithms are used.
6. To explore Deep learning technique and various feature extraction strategies.

Module 1 **(9L)**

Supervised Learning (Regression/Classification)

Basic methods: Distance-based methods, Nearest-Neighbours, Decision Trees, Naive Bayes
Linear models: Linear Regression, Logistic and Multinomial Logistic Regression: Logistic function, estimation of probability using logistic regression, Deviance, Wald's test, Hosmer Lemeshow test. Feature selection in logistic regression, Generalized Linear Models

Support Vector Machines, Nonlinearity and Kernel Methods Beyond Binary Classification: Multi-class/Structured Outputs, Ranking Basic building blocks of Naive Bayes classifier and learn how to build an SMS Spam Ham Classifier using Naive Bayes technique.

Module 2 **(7L)**

Unsupervised Learning Clustering: K-means/Kernel K-means, Dimensionality Reduction: PCA and kernel PCA Matrix Factorization and Matrix Completion, Generative Models (mixture models and latent factormodels)

Module 3 **(6L)**

Evaluating Machine Learning algorithms and Model Selection, Introduction to Statistical

Learning Theory, Ensemble Methods: Boosting, Bagging, Random Forests.

Module 4 **(8L)**
Feature Representation Learning, Deep Learning: Introduction to Neural Network, Convolutional Neural Network, Recurrent Neural Network and their applications.

Module 5 **(12L)**
Scalable Machine Learning (Online and Distributed Learning) and its applications: Social recommender systems, Real time analytics, Spam filtering, Topic modeling, Document analysis. Semi- supervised Learning, Active Learning, Inference in Graphical Models, Introduction to Bayesian Learning and Inference. Reinforcement Learning Algorithms: Markov Chains, Markov Decision Process, Policy Iteration and Value Iteration, Algorithms with applications in marketing.

- Each module is to be completed with associated algorithms.

References:
1. M. Michell, Machine Learning: McGraw Hill Education, 2017.
2. K.P. Murphy, Machine Learning: A Probabilistic Perspective, The MIT Press, Cambridge, Massachusetts London, England, 2012.
3. R. Russell, Machine Learning: Step-by-Step Guide to Implement Machine Learning Algorithms with Python, -Online Resource, Copyright 2018.
4. M. Mohammed, M.B. Khan and E.B.M. Bashier,Machine Learning: Algorithms and Applications, 2017, CRC press.

Relationship of CO with PO mapping:

CO	**PO**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Data Science-1: Machine Learning (MS-AM302)										
CO1: To learn the concept of how to learn patterns and concepts from data	S	S	S	S	S	S	S	M	S	S
CO2: Understand applications of ML in various functional areas & industries.	S	S	S	M	S	S	S	M	M	S
CO3: To design and analyse various machine learning algorithms and techniques with a modern outlook focusing on recent advances.	S	S	S	M	S	S	S	M	M	S
CO4: To explore supervised and unsupervised learning paradigms of machine learning.	S	S	S	M	S	S	M	M	M	S
CO5: To understand how reinforcement and	S	S	S	S	S	M	M	M	M	S

evolutionary algorithms are used.										
CO6: To explore Deep learning technique and various feature extraction strategies.	S	S	S	S	S	M	M	L	M	S

S- Strong; M-Medium; L-Low

Integral Transforms and Integral Equations	**Course Code: MS-AM303** **4 Credits, 100 marks**

Course Objectives:

1. To understand and apply the fundamental concepts integral transform
2. To understand the concept of Laplace transform, Fourier transform, Hankel transform, Mellin transform and Z transform.
3. To introduce the basics of integral equation
4. To understand the applications of mathematical transform
5. To understand the applications of integral equation.

Module 1 **12L**

Laplace Transform: Definition, Transform of some elementary functions, rules of manipulation of Laplace Transform, Transform of Derivatives, relation involving Integrals, the error function, convolution of two functions, Inverse Laplace Transform of simple function, Solution of Differential Equations-Initial value problems for linear equations with constant coefficients, two-point boundary value problem for a linear equation with constant coefficients, linear differential equation with variable coefficients, simultaneous differential equations with constant coefficients, Solution of diffusion and wave equation in one dimension and Laplace equation in two dimensions.

Module 2 **10L**

Fourier Series and Fourier Transforms: Orthogonal set of functions, Fourier series, Fourier sine and cosine series, Half range expansions.
Fourier integral Theorem, Fourier Transform, Fourier Cosine Transform, Fourier Sine Transform, Transforms of Derivatives, Fourier transforms of simple Functions, Fourier transforms of Rational Functions, Convolution Integral, Parseval's Theorem for Cosine and Sine Transforms, Inversion Theorem, , Solution of Partial Differential Equations by means of Fourier Transforms. First order and second order Laplace and Diffusion equations.

Module 3 **10L**

Hankel Transform: Elementary properties, Inversion theorem, transform of derivatives of functions, transform of elementary functions, Parseval relation, relation between Fourier and Hankel transform, use of Hankel Transform in the solution of Partial differential equations, Dual integral equations and mixed boundary value problems.

Mellin Transforms-The Mellin inversion theorem- some elementary properties of Mellin Transforms and Mellin Transfroms of derivatives – Mellin Integrals- Convolution Theorem.
Definition and properties of Z- Transforms, Inverse Z- Transforms, and Application of Z- Transforms to difference equations.

Module 4 **12L**

Definition and classification, conversion of initial and boundary value problems to an integral equation, Eigen-Values and Eigen functions. Solutions of homogeneous and general Fredholm integral equations of second kind with separable kernels. Solution of Fredholm and Volterra integral equations of second kind by methods of successive substitutions and successive approximations, Resolvent kernel and its results. Solution of Volterra integral equations with convolution type kernels by Laplace transform.

References:
1. Ian N. Sneddon, The use of Integral Transforms, McGraw Hill; Second Printing edition, 1972.
2. Ian N. Sneddon, Fourier Transforms, Dover Publications, 2010.
3. L. Debnath, Integral Transforms and their applications, Chapman and Hall/CRC; 2 editions, 2006.
4. E. Kreyszig, "Advanced Engineering Mathematics (8th Edition)", Wiley-India (2007).
5. W. V. Lovitte, Linear Integral Equations, over Publications; Reissue edition, (2005).
6. R. P. Kanwal, Linear Integral Equations, Birkhäuser, 2nd edition, (1996).
7. S.G. Mikhlin, Linear Integral Equations, Routledge, (1961).
8. A. M. Wazwaz, A first Course in Integral Equation, World Scientific Publishing Co. Pte. Ltd, 2015.

Relationship of CO with PO mapping:

CO	PO									
	1	2	3	4	5	6	7	8	9	10
Integral Transforms and Integral Equations(MS-AM303)										
CO1: To understand and apply the fundamental concepts integral transform	S	S	S	S	S	S	S	M	M	S
CO2: To understand the concept of Laplace transform, Fourier transform, Hankel transform, Mellin transform and Z transform.	S	M	S	S	S	S	M	M	L	S
CO3: To introduce the basics of integral equation	S	S	S	S	S	S	S	M	M	S
CO4: To understand the applications of mathematical transform	S	M	S	S	M	S	M	M	M	S
CO5: To understand the applications of integral equation.	S	M	S	S	S	S	S	M	M	S

S- Strong; M-Medium; L-Low

Computational Biology	**Course Code: MS-AM304** **4 Credits, 100 marks**

Course Objectives:
1. To understand and apply the fundamental concepts of mathematics in biology
2. To apply mathematics in real life biological model

3. To introduce the computational methodology for biological problem
4. To understand the various types of bioinformatics model
5. To analyze and visualization of biological problem using programming language and different software

Module 1 **12L**

Compositions of functions, Modeling basic life science scenarios in calculus like simple cases of drug concentration, energy consumption, Fick's law, Flow of blood, growth of bacteria, estimates of inoculation, Poiseuille's law, population growth, Logistic Growth Model and its extensions, recall rate of memory, respiration, spread of an epidemic, air and water pollution. Bifurcation Phenomena in Population models.

Module 2 **10L**

Concepts of differentiation, anti-differentiation, differential equations, difference equation, functions of several variables as needed to study population dynamics, biophysical models.

Module 3 **10L**

Visualization: Graph Types in Biology -bar graphs, line graph, area graph, scatter plot, pie and 3-dimensional graphs and generation using simple programs like Excel, Octave or Matlab.

Module 4 **12L**

Introduction to Genes and Proteins, Sequence Information Sources, Protein Information Sources, Introduction to Data Generating Techniques.

References:

1. William K. Purves, David E. Sadava, Gordon H. Orians and H. Craig Heller, Life: The Science of Biology, 7th Edition, Sinauer Associates and W.H. Freeman, 2003
2. J.D. Murray, Mathematical Biology, Third Edition, Springer, 2002.
3. C. Fall, Computational Cell Biology, Springer, 2000.
4. R. Galina Yur'evna, Mathematical models in Biophysics, Book Online, Biophysical society(Web Source as on 04.08.2021 https://www.biophysics.org/Portals/0/BPSAssets/Articles/galina.pdf)
5. L. D. Hoffmann, Calculus: for the social, managerial and life sciences –McGraw Hill, 1980
6. E. Kreyszig, Advanced Engineering Mathematics, John Wiley and Sons, 2001.

Relationship of CO with PO mapping:

CO	PO									
	1	2	3	4	5	6	7	8	9	10
Computational Biology(MS-AM304)										
CO1: To understand and apply the fundamental concepts of mathematics in biology	S	S	S	S	M	S	M	M	M	S
CO2: To apply mathematics in real life biological model	S	S	S	S	S	S	S	S	M	M

CO3: To introduce the computational methodology for biological problem	S	S	S	S	S	M	M	S	M	S
CO4: To understand the various types of bioinformatics model	S	M	S	S	S	S	M	M	L	S
CO5: To analyze and visualization of biological problem using programming language and different software	S	M	S	S	S	M	M	S	M	S

S- Strong; M-Medium; L-Low

Elective –II (IDE):

Quantum Information and Computation	**Course Code: MS-AM305A** **3 Credits, 100 marks**

Course Objectives:

1. To develop the skill to deal with the new frontier of new quantum technology.
2. To make the student acquainted with the basic principles of quantum mechanics which is relevant to quantum computation.
3. To introduce the principles of quantum information and their relation to classical information.
4. To introduce the basic theory of quantum entanglement and its uses.

Module 1 9L

The description of Ket vectors. Operator theory on Ket space. Quantum evolution operator. Quantum measurement. Definition of qubits as units of quantum information. Comparison of qubits with classical bits.

Module 2 **9L**

Quantum entanglement- definition and elementary properties. Bell's states and GHZ –states as entangled states. Measures of quantum entanglement through quantum entropy. Maximally entangled states. Uses of entangled states as quantum resources.

Module 3 **8L**

The quantum no-cloning theorem. The quantum no-deletion theorem. Transmission of quantum information. Teleportation protocols. Quantum remote state preparation protocols.

Module 4 **8L**

Quantum gates. Elements of quantum circuits and networks. Concepts of quantum cryptography. BB84 protocol.

Module 5 **8L**

Quantum integral transforms. Quantum algorithms. Deutsch algorithm. Shor's factorization algorithm. Grover's search algorithm.

References:

1. M.A. Nielsen and I. L. Chuang, Quantum Computation and Quantum Information, Cambridge University Press, Cambridge, 2000.
2. M. Nakahara and T. Ohmi, Quantum Computing, CRC Press, New York, 2008.
3. G. Benenti, G. Casati, D. Rossini and G. Strini, Principles of Quantum Information and Computation: A Comprehensive Textbook, World Scientific, Singapore, 2019.

Relationship of CO with PO mapping:

CO	**PO**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Quantum Information and Computation (MS-AM305A)										
CO1: To develop the skill to deal with the new frontier of new quantum technology.	S	M	S	S	S	S	M	S	S	S
CO2: To make the student acquainted with the basic principles of quantum mechanics which is relevant to quantum computation.	S	M	M	S	M	S	S	M	M	S
CO3: To introduce the principles of quantum information and their relation to classical information.	S	S	S	M	M	S	M	M	L	M
CO4: To introduce the basic theory of quantum entanglement and its uses.	S	M	S	S	M	S	M	M	M	S

S- Strong; M-Medium; L-Low

Mathematical Epidemiology	**Course Code: MS-AM305B** **4 Credits, 100 marks**

Course Objectives:

1. To understand and apply the fundamental concepts of mathematics in epidemiology
2. To apply mathematics in epidemiological model
3. To introduce the computational methodology for epidemiological problem
4. To understand the various types of epidemiological model
5. To analyze and visualization of biological problem using programming language and different software

Module 1 **12L**

Compositions of functions, Modeling basic life science scenarios in calculus like simple cases of drug concentration, energy consumption, Fick's law, Flow of blood, growth of bacteria, estimates of inoculation, poiseuille's law, population growth, recall rate of memory, respiration, spread of an epidemic, air and water pollution.

Module 2 **10L**

Population models associated with ordinary differential equations and difference equation. Equilibrium points, phase diagrams and solutions fields, competing species and predator-prey models, continuous and discrete Dynamical systems.

Module 3 **10L**

Introducing the SIR and SIS models, The SIR Model with demography, Modeling vector-borne diseases.

Module 4 **12L**

Building more complex ODE epidemic models. Techniques for computation of R_0, Fitting ODE epidemic models to data, Structural and practical identifiability.

References:

1. Erwin Kreyszig, Advanced Engineering Mathematics, John Wiley and Sons, 2001.
2. Christopher Fall, Computational Cell Biology, Springer, 2000.
3. R. Galina Yur'evna, Mathematical models in Biophysics, Book Online, Biophysical society (Web Source as on 04.08.2021 https://www.biophysics.org/Portals/0/BPSAssets/Articles/galina.pdf)
4. Laurence D. Hoffmann, Calculus: for the social, managerial and life sciences, McGraw Hill, 1980.

Relationship of CO with PO mapping:

CO	**PO**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Mathematical Epidemiology (MS-AM305B)										
CO1: To understand and apply the fundamental concepts of mathematics in epidemiology	S	S	M	S	M	S	S	S	M	S
CO2: To apply mathematics in epidemiological model	S	S	S	S	S	S	M	M	M	S
CO3: To introduce the computational methodology for epidemiological problem	S	M	S	S	M	S	S	M	M	S
CO4: To understand the various types of epidemiological model	S	S	S	S	M	S	M	M	M	S
CO5: To analyze and visualization of biological problem using programming language and different software	S	S	S	S	S	M	M	L	M	M

S- Strong; M-Medium; L-Low

Mathematical Modeling of Biological Systems	**Course Code: MS-AM305C** **4 Credits, 100 marks**

Course Objectives:

1. To understand and apply the fundamental concepts of mathematics in biology
2. To apply mathematics in real life biological model
3. To introduce the computational methodology for biological problem
4. To understand the various types of biomathematics model
5. To analyze and visualization of biological problem using programming language and different software

Module 1 **12L**

Population dynamics, growth and decay model, Growth and spatial spread of organisms, blood stream flow.

Module 2 **10L**

Population models associated with ordinary differential equations such as SIR, SIS, SIRS etc, equilibrium points, phase diagrams and solutions fields, competing species and predator-prey models – Dynamical systems, Euler's method, and solving linear dynamical systems.

Module 3 **10L**

Discrete change in biological population systems, Difference equations and discrete dynamical systems, solutions and stability

Module 4 **12L**

Modeling diabetes, HIV, Leprosy etc, solution of model using MATLAB and mathematica with stability analysis, co infection problem.

References:

1. G. Eason, Mathematics and Statistics for the Biosciences, Pearson-Education, 1992.
2. J D Murray, Mathematical Biology, Third edition, Springer, 2002.
3. Robert Jackson, Seven Equations of Life: The Fundamental Relationships of Biomathematics, Lap Lambert, 2016.
4. Laurence D. Hoffmann, Calculus: for the social, managerial and life sciences, McGraw Hill, 1980.
5. Martin Nowak, Evolutionary Dynamics, Harvard University Press, 2006.

Relationship of CO with PO mapping:

CO	**PO**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Mathematical Modeling of Biological Systems(MS-AM305C)										
CO1: To understand and apply the fundamental	S	S	S	M	M	S	M	M	M	S

concepts of mathematics in biology										
CO2: To apply mathematics in real life biological model	S	S	S	S	M	S	S	S	M	S
CO3: To introduce the computational methodology for biological problem	S	S	S	S	M	S	S	M	M	S
CO4: To understand the various types of biomathematics model	S	M	S	M	M	S	M	M	L	M
CO5: To analyze and visualization of biological problem using programming language and different software	S	S	S	M	S	M	S	M	M	S

S- Strong; M-Medium; L-Low

Astrophysics and Cosmology	**Course Code: MS-AM305D** **4 Credits, 100 marks**

Course Objectives:

1. To develop an interest in cosmology and astrophysics.
2. To describe the working principle of astronomical tools and discuss physical processes in stars and evolution of stars.
3. To explain how natural sciences work and explore the structure and dynamics of galaxies.
4. To understand the astronomical objects and processes based on fundamental physical principles.

Module 1: General Theory of Relativity and Cosmology-I: (6L)

Cosmology, Homogeneity and isotropy of the universe, Weyl Postulate, Cosmological principle, General relativistic cosmological models, Cosmological observations, Olbers Paradox, Friedmann Cosmological Models, Cosmologies with a non-zero λ, Hubble's Law, Age of the Universe, Gravitational red shift and Cosmological redshift, Spherically symmetric space-time: Schwarzschild solution, Newtonian approximation, Photon orbits, Birkhoffs theorem. Equilibrium of Massive spherical objects, The Schwarzschild Interior solution, Structure of the star, Gravitational collapse, White dwarfs, Neutron Stars.

Module 2: **Cosmology-II (12L)**

Gravitational collapse of a homogeneous dust ball, Schwarzschild black hole, Black hole physics, Minkowski space-time: Past and future Cauchy development, Cauchy surface, DeSitter and anti-de Sitter space-times. Robertson-Walker spaces, Spatially homogeneous space-time models, The Schwarzschild and Reissner - Nordstrom solutions, Kruskal diagram, Causal structure, Orientability, Causal curves, Causality conditions, Cauchy developments, Geodesics, Causal boundary of space-time, Asymptotically simple spaces.

Module 3: AstrophysicsI: Application of General Relativity (14L)
Brief history on formation and evolution of stars, Schwarzschild exterior solution, Birkhoff's theorem, Schwarzschild singularity, Kruskal's transformation, Schwarzschild Black hole. Motion of test particles around Schwarzschild black hole, Kerr metric and Kerr black holes, Horizons, Interior of Schwarzschild metric, massive objects, Opcnheimer -Volkoff limit, Gravitational lensing, Quasars , Pulsars, Supernova, Gravitational collapse, Accretion into compact objects, Boltzmann formula, Saha Ionization equation, H-R diagram

Module 4: Astrophysics II: (6L)
Plasma, black Body, Cherenkov & Synchroton Radiation, Accreation & Quasar as source of radiation, Compton effect, Formation of Galactic Structure - different Theories, Formation of Galaxy in Evolutionary Universe & Steady State Universe, Possibility of galactic structure formation through Explosion, Hubble's Law & Expansion of Universe -Big Bang Model, Uniformity of Large Scale Structure, Origin of Cosmic Rays, Galaxies and the Universe.

References:
1. Astrophysics- B. Basu
2. The General Theory of Relativity-A mathematical Approach- F. Rahaman
3. The Structure of Universe- J.V. Narlikar
4. Gravitation & Cosmology- S. Weinberg
5. General Relativity, Astrophysics & Cosmology- Raychowdhury, Banerji & Banerji
6. An Introduction to Mathematical Cosmology- J. N. Islam (Camb Univ Press)

Relationship of CO with PO mapping:

CO	PO									
	1	2	3	4	5	6	7	8	9	10
Astrophysics and Cosmology(MS-AM305D)										
CO1: To develop an interest in cosmology and astrophysics.	S	S	S	M	M	S	M	M	M	S
CO2: To describe the working principle of astronomical tools and discuss physical processes in stars and evolution of stars.	S	M	S	S	M	S	M	M	M	S
CO3: To explain how natural sciences work and explore the structure and dynamics of galaxies.	S	M	M	S	M	S	M	M	L	S
CO4: To understand the astronomical objects and processes based on fundamental physical principles.	S	M	S	S	M	S	M	M	M	M

S- Strong; M-Medium; L-Low

Maulana Abul Kalam Azad University of Technology, West Bengal
Course: M.Sc in Applied Mathematics,
Effective from Academic Session: 2021-22
Duration: 2 Years (4 semesters); Level: Post graduation; Type: Degree

Advanced Data Science	**Course Code:MS-AM305E** **4 Credits, 100 marks**

Course Objective:

1. To gain basic knowledge of data and information.
2. To understand the history, potential application area and future of data sscience.
3. To produce Python code to statistically analysis a dataset.
4. To critically evaluate data visualisations based on their design and use for communicating stories from data;
5. To demonstrate an understanding of statistics and machine learning concepts that are vital for data science.

Module 1: 10L

Introduction to core concepts and technologies: Introduction, Terminology, data science process, data science toolkit, Types of data,
Data collection and management: Introduction, Sources of data, Data collection and APIs, Exploring and fixing data, Data storage and management, Using multiple data sources

Module 2: 10L

Data analysis: Introduction, Terminology and concepts, Introduction to statistics, Central tendencies and distributions, Variance, Distribution properties and arithmetic, Samples/CLT, Basic machine learning algorithms, Linear regression, SVM, Naive Bayes.

Module 3: 10L

Data visualisation: Introduction, Types of data visualisation,Data for visualisation:Data types, Data encodings, Retinal variables, Mapping variables to encodings, Visual encodings.
Applications of Data Science: Technologies for visualisation, Bokeh (Python)

Module 4: 10L

Recent trends: various data collection and analysis techniques, various visualization techniques, application development methods of used in data science.

References:

1. J. Han, M. Kamber and J. Pei, Data Mining: Concepts and Techniques, Third Edition, Elsevier, 2012.
2. P.N. Tan, M. Steinbach and V. Kumar: Introduction to Data Mining, Pearson, 2014.
3.C. O'Neil and R. Schutt, Doing Data Science, Straight Talk From The Frontline, O'Reilly.
4.J. Leskovek, A. Rajaraman and J. Ullman, Mining of Massive Datasets. v2.1 Cambridge University Press

Relationship of CO with PO mapping:

CO	**PO**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

Advanced Data Science (MS-AM305E)										
CO1: To gain basic knowledge of data and information.	S	S	S	S	S	M	S	M	M	S
CO2: To understand the history, potential application area and future of data sscience.	S	M	S	S	S	M	M	M	L	M
CO3: To produce Python code to statistically analysis a dataset.	S	S	S	S	S	M	S	M	M	S
CO4: To critically evaluate data visualisations based on their design and use for communicating stories from data;	S	M	S	S	M	S	S	S	M	S
CO5: To demonstrate an understanding of statistics and machine learning concepts that are vital for data science.	S	M	S	S	M	M	M	M	L	S

S- Strong; M-Medium; L-Low

Mathematics for Finance	**Course Code: MS-AM305F** **4 Credits, 100 marks**

Course Objective:

1. Provide an introduction to financial instruments related to financial mathematics;
2. Introduce students to the use of mathematical models for financial products;
3. Develop student abilities to create, derive, and apply mathematical models.
4. Compute standard Value At Risk and understand assumptions behind it.
5. Derive Black-Scholes equations using risk-neutral arguments.
6. Understand Ito's lemma and its applications in financial mathematics.
7. Understand Girsanov's theorem and change of measure.

Module-1 **6L**

Introduction to financial markets, financial instruments, bonds, stocks and financial derivatives. Time value of money, simple and compound interest rate, net present value, internal rate of return and annuities.

Module-2 **10L**

Markowitz portfolio theory, risk and return, two and multi asset portfolio theory, efficient Frontier, Capital Asset Pricing Model and portfolio performance analysis.
No arbitrage principle, pricing of forwards and futures, properties of options.

Module-3 **10L**

Derivative pricing by replication in binomial model, Discrete probability spaces, filtration, conditional expectation, Discrete time martingales, Markov chain, risk-neutral pricing in binomial model for

European and American derivatives, General probability spaces, conditional expectation, Brownian motion.

Module-4 **16L**

Ito integral, Ito formula, Stratonovich Integral, Girsanov's theorem, martingale representation theorem, Stochastic differential equation, Black-Scholes-Merton (BSM) model, Critique of BSM model, Pricing of European derivatives in BSM framework, Valuation of European options in BSM model, BSM formula, BSM partial differential equation, Hedging, Model completeness, fundamental theorems of asset pricing.

References:

1. A. O. Petters and X. Dong, An Introduction to Mathematical Finance with Applications, Springer, 2016.
2. M. Capi´nski and T. Zastawniak, Mathematics for Finance: An Introduction to Financial Engineering, Springer-Verlag, 2003.
3. G. Gan, C. Ma and H.Xie Measure, Probability, And Mathematical Finance: A Problem-Oriented Approach, John Wiley & Sons, 2014.
4. Web Reference as on 04.08.2021: https://ocw.mit.edu/courses/mathematics/18-s096-topics-in-mathematics-with-applications-in-finance-fall-2013/lecture-notes/

Relationship of CO with PO mapping:

CO	**PO**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Mathematics for Finance (MS-AM305F)										
CO1: Provide an introduction to financial instruments related to financial mathematics;	S	S	S	S	M	M	M	M	M	S
CO2: Introduce students to the use of mathematical models for financial products;	S	S	M	M	M	M	S	L	M	S
CO3: Develop student abilities to create, derive, and apply mathematical models.	S	S	S	S	M	S	M	M	M	M
CO4: Compute standard Value At Risk and understand assumptions behind it.	S	S	S	S	M	S	M	M	L	S
CO5: Derive Black-Scholes equations using risk-neutral arguments.	S	M	M	S	M	S	M	L	M	M
CO6: Understand Ito's lemma and its applications in financial mathematics.	S	S	S	S	M	S	M	M	L	S
CO7: Understand Girsanov's theorem and change of measure.	S	M	M	S	M	S	M	M	M	M

S- Strong; M-Medium; L-Low

Actuarial Science	**Course Code: MS-AM305G** **4 Credits, 100 marks**

Course Objectives:

1. To equip students with a high level of knowledge on the Actuarial theory and practice and their various applications in practice.
2. To enable students to become efficient decision makers when they have to occupy positions where an actuarial expertise and risk theory are an essential component.
3. To enable students to disseminate acquired knowledge by acting as resource persons for imparting such knowledge to others.
4. To enthuse students to use such acquired knowledge as a foundation for developing professional skills to promote public interest.
5. The course also aims to give solid grounding for further intensive studies and research which are now highly in demand in the field of insurance, banking, investment, financial services, risk management, regulatory needs etc.

Module 1: **10L**

Introductory Statistics and Insurance Applications: Discrete, continuous and mixed probability distributions. Insurance applications, sum of random variables. Utility theory: Utility functions, expected utility criterion, types of utility function, insurance and utility theory.

Module 2: **10L**

Principles of Premium Calculation: Properties of premium principles, examples of premium principles. Individual risk models: models for individual claims, the sum of independent claims, approximations and their applications.

Module 3: **10L**

Survival Distribution and Life Tables: Uncertainty of age at death, survival function, time- until-death for a person, curate future lifetime, force of mortality, life tables with examples, deterministic survivorship group, life table characteristics, assumptions for fractional age, some analytical laws of mortality.

Module 4: **10L**

Life Insurance: Models for insurance payable at the moment of death, insurance payable at the end of the year of death and their relationships. Life annuities: continuous life annuities, discrete life annuities, life annuities with periodic payments. Premiums: continuous and discrete premiums.

References:

1. C. M. D. Dickson, (2005): Insurance Risk and Ruin (International Series On Actuarial Science), Cambridge University Press.
2. N. L., Bowers, H. U., Gerber, J. C., Hickman, D. A. Jones and C. J. Nesbitt, (1997): Actuarial Mathematics, Society Of Actuaries, Itasca, Illinois, U.S.A.

Relationship of CO with PO mapping:

CO	**PO**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Actuarial Science (MS-AM305G)										
CO1: To equip students with a high level of knowledge on the Actuarial theory and practice and their various applications in practice.	S	M	S	S	M	S	S	M	M	S
CO2: To enable students to become efficient decision makers when they have to occupy positions where an actuarial expertise and risk theory are an essential component.	S	S	S	M	M	S	M	M	L	S
CO3: To enable students to disseminate acquired knowledge by acting as resource persons for imparting such knowledge to others.	S	S	M	S	M	M	M	M	M	S
CO4: To enthuse students to use such acquired knowledge as a foundation for developing professional skills to promote public interest.	S	S	S	M	M	S	M	M	L	M
CO5: The course also aims to give solid grounding for further intensive studies and research which are now highly in demand in the field of insurance, banking, investment, financial services, risk management, regulatory needs etc.	S	S	M	S	M	M	S	S	M	S

S- Strong; M-Medium; L-Low

Machine Learning Lab	**Course Code: MS-AM391(LAB)** **2 Credits, 100 marks**

Course Objectives:

1. To introduce students to the basic techniques of Machine Learning.
2. To develop skills of using recent machine learning software for solving practical problems.
3. To enable the students to: state-of-the-art methods and modern programming tools for data analysis using machine learning programs and algorithms
4. To gain experience of doing independent study and research.

Sl. No.	Topics
1.	Linear regression, Decision trees, overfitting.
2.	Instance based learning, Feature reduction,
3.	Bayes Decision Theory
4.	Logistic Regression, Support Vector Machine, Kernel function and Kernel SVM.
5.	Neural network: Perceptron, multilayer network, backpropagation, introduction to deep neural network.
6.	Clustering: k-means, adaptive hierarchical clustering, Gaussian mixture model.

References:

1. R. Russell-Machine Learning: Step-by-Step Guide to Implement Machine Learning Algorithms with Python, Online Resource, Copyright 2018.
2. M. Mohammed, M.B. Khan and E.B.M. Bashier,Machine Learning: Algorithms and Applications, 2017, CRC press
3. A. C. Müller and Sarah Guido, O'REILLY,Introduction to Machine learning with python, 2016
4. J. Jose, Introduction to Machine Learning using Python, Khanna Publishing House

Relationship of CO with PO mapping:

CO	**PO**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Machine Learning Lab(MS-AM391(LAB))										
CO1: To introduce students to the basic techniques of Machine Learning.	S	S	S	S	S	M	M	M	M	S
CO2: To develop skills of using recent machine learning software for solving practical problems.	S	S	S	S	S	S	M	S	M	S
CO3: To enable the students to: state-of-the-art methods and modern programming tools for data analysis using machine learning programs and algorithms	S	S	S	S	S	M	M	M	L	S
CO4: To gain experience of doing independent study and research.	M	M	S	S	M	M	S	S	S	S

S- Strong; M-Medium; L-Low

Differential Equation and Integral Transform Lab	**Course Code: MS-AM392(LAB)** **2 Credits, 100 marks**

Course Objectives:

1. To present the foundations of many basic Mathematical tools and concepts related Engineering.
2. To provide a coherent development to the students for the courses of various branches of Engineering like Control Theory, Circuits and Networks, Digital Logic design, Fluid Mechanics, Machine Design etc.
3. To enhance the student's ability to think logically and mathematically.
4. To give an experience in the implementation of Mathematical concepts which are applied in various field of Engineering.

Chapter	**Name of the topic**	**Hours**
01	Solving ordinary differential equations using simple iteration methods	4
02	Spectral collocation method for linear ODEs	2
03	Spectral quasilinearization method for nonlinear ODEs	4
04	Linear Partial differential equation	4
05	Nonlinear evolution partial differential equations	2
06	Integral transform in fractional equation: fractional ODE, integrals, Laplace Transform of fractional integral and derivatives	4

07	Application to boundary value problems	2
08	Applications to integral and differential equations	4
09	Application to electrical circuit	4
10	Application to wavelet transform	4

References:

1. E. Kreyszig, "Advanced Engineering Mathematics (8th Edition)", by Wiley-India, 2007.
2. E. Rukumangadachari, Differential Equations, Pearson India, 2014.
3. W. E. Boyce and R. DiPrima, "Elementary Differential Equations (8th Edition)", John Wiley, 2005.
4. M.D. Raisinghania, Ordinary and Partial Differential Equations, S Chand & Co., 2016.
5. G. B. Folland, Introduction to Partial Differential Equations, 2nd edition, Prentice Hall of India, 2001.
6. C. E. Froberg, Introduction to Numerical Analysis (2nd Edition), Addison-Wesley,
7. MK Jain, Numerical Solutions of Differential Equations, 2nd Edition, Wiley Eastern Ltd, 1984.
8. M.K. Jain, S.R.K. Iyengar and R.K. Jain, Computational Methods for partial differential equation, 2nd Edition, New Age International Publishers, 1994.

Relationship of CO with PO mapping:

CO	**PO**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Differential Equation and Integral Transform Lab (MS-AM392(LAB))										
CO1: To present the foundations of many basic Mathematical tools and concepts related Engineering.	S	S	S	S	S	S	M	M	M	S
CO2: To provide a coherent development to the students for the courses of various branches of Engineering like Control Theory, Circuits and Networks, Digital Logic design, Fluid Mechanics, Machine Design etc.	S	M	S	S	S	M	M	L	L	S
CO3: To enhance the student's ability to think logically and mathematically.	S	M	S	S	S	M	M	M	M	S
CO4: To give an experience in the implementation of Mathematical concepts which are applied in various field of Engineering.	S	S	S	S	S	S	S	M	M	S

S- Strong; M-Medium; L-Low

Maulana Abul Kalam Azad University of Technology, West Bengal
Course: M.Sc in Applied Mathematics,
Effective from Academic Session: 2021-22
Duration: 2 Years (4 semesters); Level: Post graduation; Type: Degree

Semester-4:

Probability and Statistical Method	Course Code: MS-AM401 4 Credits, 100 marks

Course Objectives:

1. To understand the axiomatic formulation of modern Probability Theory and think of random variables as an inherent need for the analysis of random phenomena.
2. To characterize probability models and function of random variables based on single & multiples random variables and their distributions.
3. To evaluate and apply moments & characteristic functions and understand the concept of inequalities and probabilistic limits.
4. To perform Test of Hypothesis as well as calculate confidence interval for a population parameter and to understand the concept of p-values.
5. To provide students with the foundations of probabilistic and statistical analysis mostly used in varied applications in engineering and science like disease modelling, climate prediction and computer networks etc.

Module 1 **(10L)**

Genesis of probability Theory, Emergence of probability as an analytics tool, Sample space, Events, Classical definition of probability and its limitations, Kolmogorov's Axiomatic definition of probability, Classical definition as a special case of axiomatic definition, total probability, joint and conditional probabilities, independence, Bayes' theorem and Bayesian inference paradigm and it's applicability, Prior and Posterior distributions, Bayesian Statistics vs Classical vs frequentist approach.

Module 2 **(12L)**

Random Variables and its distributions, Concept of location, spread, shape of a probability distribution, Generating functions, Emergence of random variable in real life, Probability models, Discrete and Continuous distributions, Some special distributions: Binomial, Poisson, Negative Binomial, Uniform, Exponential, Chi-square, Normal distributions, Functions of random variables, Derived random variable and their distributions.

Stochastic inequalities and their applications, Convergence in probability, Law of large numbers; Central limit theorems and its significance.

Module 3: **(12L)**
Concept of Bivariate Distributions, Marginal distributions, correlation and regression analysis.
Types of Sampling, Parameter & Statistics, Sampling distributions; point and interval estimation, Confidence Interval, Estimation of Parameters, Maximum likelihood Estimates & MAP, Interval Estimation.

Testing of Hypothesis: Setting up null and alternative hypothesis based on real problems, Power and size of a statistical test and their interpretation, p-value and its implications.

Test of Significance for large sample, Application of hypothesis testing across different real situations, Student's t, Fisher's t, Pearsonian Chi Square Statistics, ANOVA.

Neymann Pearson Lemma and its application, UMP Tests, Likelihood Ratio Test.
Chi-Square Test for Independence, Chi-Square Test for Goodness-of-Fit.

Module 4: **(8L)**

Non-Parametric methods, Sign Test, Paired sign test, Mann Whitney test, Run Test, Kruskal Walli's Test, Matched Pair Test, Friedman's test, Ansari Bradley Test, Mann Kendall trend test, Confidence Interval, Sample size determination in real life, Stein's two stage procedure.

References:

1. S. M. Ross, "Introduction to Probability and Statistics for Engineers and Scientists", Academic Press, 2009.
2. Goon, Gupta, Dasgupta, Fundamental of Statistics Vol 1, World Press 1991.
3. P. Mukhopadhyay, Theory of Probability, New Central Book Agency,1991.
4. T. Cacoullos, Exercise in Probability, Narosa Publishing House,1992.
5. R.V. Hogg, Joseph W. McKean and Allen Craig, Introduction to Mathematical Statistics, 8th edition, 2019, Pearson.
6. G. Casella, R. L. Berger, Statistical Inference, 2nd edition, Duxbury Advanced Series, 2009.

Relationship of CO with PO mapping:

CO	**PO**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Probability and Statistical Method(MS-AM401)										
CO1: To understand the axiomatic formulation of modern Probability Theory and think of random variables as an inherent need for the analysis of random phenomena.	S	S	S	S	M	S	S	S	M	S
CO2: To characterize probability models and function of random variables based on single & multiples random variables and their distributions.	S	M	M	S	M	S	S	M	M	S
CO3: To evaluate and apply moments & characteristic functions and understand the concept of inequalities and probabilistic limits.	S	M	S	S	S	M	M	M	M	S
CO4: To perform Test of Hypothesis as well as calculate confidence interval for a population parameter and to understand the concept of p-	S	M	S	S	M	M	M	L	M	M

values										
CO5: To provide students with the foundations of probabilistic and statistical analysis mostly used in varied applications in engineering and science like disease modelling, climate prediction and computer networks etc.	S	S	S	S	M	S	S	M	M	M

S- Strong; M-Medium; L-Low

Operation Research: Optimization Techniques and Soft Computing	**Course Code: MS-AM402** **4 Credits, 100 marks**

Course Objectives:

1. To transform real life minima/maxima problems into optimization framework.
2. To learn efficient computational procedures to solve linear and non-linear optimization problems.
3. To acquire an idea about the various direct and indirect search methods.
4. To learn applicability of different queuing models in real life cases.
5. To learn the different soft computing techniques including Fuzzy logic and evolutionary algorithms.

Module 1 **(6L)**

Introduction: Concept of optimization – Classification of optimization problems.
Linear Programming: Examples of linear programming problems – Formulation, Simplex methods including Charne's Penalty Method, Two Phase Method and Degeneracy, Dual simplex method, Sensitivity analysis.
Solution of the Transportation and Assignment problems, Shortest route problem.

Module 2 **(9L)**

Non-Linear Optimization Techniques:
Unconstrained Optimization: Maximization and minimization of convex functions, Necessary and sufficient conditions for local minima, Speed and order of convergence,

Univariate search methods: Direct Search Methods-Fibonacci and Golden Section Search, Descent Methods-Steepest Descent, Fletcher Reeves, Newton's and Conjugate Gradient methods.

Unconstrained Optimization Techniques: Necessary and sufficient condition for Kuhn – Tucker conditions for optimality, Lagrange's Multiplier Method, Gradient projection method, Penalty function methods.

Module 3 **(5L)**

Queueing Theory: Introduction of the queuing system, Various components of a queueing system. Pure Birth Process; Pure Death Process, Birth and Death Process, M/M/1 and M/M/c models, M/M/c model with finite waiting space, and models with a finite source of customers (machine interference problem). Semi-Markovian queueing systems: M/G/1, M/G/1 with service vacations and G/M/1.

Module 4 **(6L)**

Introduction to Soft Computing: Concept of computing systems, "Soft" computing versus "Hard" computing, Characteristics of Soft computing, Some applications of Soft computing techniques.

Fuzzy logic**:** Introduction to Fuzzy logic, Fuzzy sets and membership functions, Operations on Fuzzy sets, Fuzzy relations, rules, propositions, implications and inferences, Some applications of Fuzzy logic, Fuzzy Inference Systems,

Module 5 **(8L)**

Genetic Algorithm (GA): Differences and similarities between conventional and evolutionary algorithms, working principle, Genetic Operators- reproduction, crossover, mutation, Solving single-objective optimization problems using GAs.
Artificial Neural Networks: Biological neurons and its working, Simulation of biological neurons to problem solving, Different ANNs architectures, Applications of ANNs to solve some real life problems.

Module 6 **(6L)**

Optimization in Finance: Short term financing, asset pricing and arbitrage, portfolio selection and asset allocation, the fundamental theorem of asset pricing, arbitrage detection using LP.
Supply chain optimization problems: Introduction to Supply-Chain Optimization, Sequencing and scheduling problems in production planning, Classical machine scheduling problems.
Formulation of n -period supply-chain problem under certainty. Minimization of n period costs subject to stock conservation constraints.
Myopic Supply Policy with Stochastic Demands.

References:
1. H. A. Taha. “operations Research, An Introduction”, PHI, India, 2002.
2. S. S. Rao, “Engineering Optimization: Theory and Practice”, 4th Edition, John Wiley & Sons (2009).
3. D. Gross and C. M. Harris, Fundamentals of Queueing Theory, Wiley, 2018
4. T. J. Ross, Fuzzy Logic with Engineering Applications (3rd Edn.), Willey, 2010.
5. N. K. Kasabov, Foundations of Neural Networks, Fuzzy Systems, and Knowldge Engineering, MIT Press, 1998.
6. M. Mitchell, An Introduction to Genetic Algorithms, MIT Press, 2000.

7. D. E. Goldberg, Genetic Algorithms in Search, Optimization and Machine Learning, Pearson Education, 2002.
8. D. K. Pratihar, Soft Computing, Narosa, 2008.
9. S. Haykin, Neural Networks and Learning Machines, (3rd Edn.), PHI Learning, 2011.

Relationship of CO with PO mapping:

CO	**PO**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Operation Research: Optimization Techniques and Soft Computing (MS-AM402)										
CO1: To transform real life minima/maxima problems into optimization framework.	S	S	S	S	S	S	M	M	M	S
CO2: To learn efficient computational procedures to solve linear and non-linear optimization problems.	S	M	S	S	S	S	S	M	M	S
CO3: To acquire an idea about the various direct and indirect search methods.	S	S	S	S	S	S	M	M	M	S
CO4: To learn applicability of different queuing models in real life cases.	S	S	S	S	M	M	S	M	M	S
CO5: To learn the different soft computing techniques including Fuzzy logic and evolutionary algorithms.	S	M	S	S	S	S	M	L	M	M

S- Strong; M-Medium; L-Low

Optimization Techniques and Soft Computing Lab	**Course Code: MS-AM491(LAB)** **2 Credits, 100 marks**

Course Objectives:

1. Cast engineering minima/maxima problems into optimization framework.
2. Learn efficient computational procedures to solve optimization problems.
3. Use Matlab to implement important optimization methods.
4. Soft Computing Techniques to Improve Data Analysis Solutions is to strengthen the dialogue between the statistics and soft computing research communities.
5. Soft Computing is a consortium of methodologies which collectively provide a body of concepts and techniques for designing intelligent systems.

Chapter	**Name of the topic**	**Hours**
1	Optimization technique through software	5
2	Applications on queuing, soft computing and fuzzy logi	5
3	Applications on Markov Chain and hidden Markov models	5
4	Epidemic Modelling and Black Scholes model	5
5	Create a perceptron with appropriate no. of inputs and outputs. Train it using fixed increment learning algorithm until no changein weights is required. Output the final weights.	5

6	Create a simple ADALINE network with appropriate no. of input and output nodes. Train it using delta learning rule until no change in weights is required. Output the final weights.	5
7	Implement Union, Intersection, Complement and Difference operations on fuzzy sets. Also create fuzzy relation by Cartesian product of any two fuzzy sets and perform max-min composition on any two fuzzy relations.	5
8	Solve Greg Viot's fuzzy cruise controller using MATLAB Fuzzy logic toolbox.	5

References:

1. D. K Prathihar, Soft Computing‖, Narosa Publishing House, New Delhi, 2008.
2. E. P. K Chong, An introduction to Optimization, Stainslaw Zak, Wiley, 2017.
3. D. Bertsekas, Nonlinear Programming, Athena Scientific, 1999.

Relationship of CO with PO mapping:

CO	**PO**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Optimization Techniques and Soft Computing Lab (MS-AM491(LAB))										
CO1: Cast engineering minima/maxima problems into optimization framework.	S	S	S	M	S	S	S	M	M	S
CO2: Learn efficient computational procedures to solve optimization problems.	S	S	S	S	S	S	M	M	M	S
CO3: Use Matlab to implement important optimization methods.	M	S	S	M	M	M	S	M	M	S
CO4: Soft Computing Techniques to Improve Data Analysis Solutions is to strengthen the dialogue between the statistics and soft computing research communities.	S	S	S	M	S	M	S	L	L	S
CO5: Soft Computing is a consortium of methodologies which collectively provide a body of concepts and techniques for designing intelligent systems.	S	S	S	M	S	M	S	M	,M	S

S- Strong; M-Medium; L-Low