Department of Applied Mathematics

Defence Institute of Advanced Technology, Pune
(Deemed to be University)
(An Autonomous Organization, Department of Defence R & D)

M.Tech (Modelling & Simulation)

From the academic year 2020-21

M.Tech. (Modelling & Simulation)

Brief Introduction of Department

The Department of Applied Mathematics came into existence with the inception of Institute of Armament Studies in 1953 as Faculty of Applied Mathematics. The faculty constituted of three departments: (1) Applied Mathematics (2) Ballistics (3) Statistics. In 1991 the three departments merged into one and named it as Department of Applied Mathematics.

Department of Applied Mathematics offers a two year Multidisciplinary M. Tech. (Modelling & Simulation) programme, and also offers a Doctoral Degree programme in the areas of Applied Mathematics.This programme was provisionally accredited by NBA.

The aim of the Department was to provide training in depth knowledge of various modelling and simulation techniques and also mathematical topics to various courses conducted at DIAT.The present faculty strength of the Department is five and one visiting faculty. The Department is also actively engaged in handling the projects from various agencies. Since then the Department members have been actively involved in the research in different fields of applied mathematics such as ballistics, flight dynamics, hydro-dynamics, hydro-ballistics, Numerical Methods and Optimization, Statistics, Probability. Recently the Department has also developed expertise in the advanced Modelling and Simulation techniques like Neural Network, Fuzzy Logic and Genetic Algorithm, Parallel Computing, Cryptography and Machine Learning.

The programmeis of two years duration where the student undergoes basic training in the subjects related to mathematical modelling & simulation through classroom teaching in the first and second year. During this period the student is also exposed to various simulation tools and practicals. The second year is the dissertation phase where the student works under the guidance of a recognized guide on a problem related to modelling and simulation. Course curriculum will be updated periodically to keep pace with contemporary technological advancement.

Research Areas

- Mathematical Modelling & Simulation
- Finite Element Analysis in Fluid Flow through Porous Media
- Computational Fluid Dynamics
- Partial Differential Equations & its Applications
- Numerical Methods for PDEs
  - Finite Elements Method
  - Boundary Element Method
  - Domain Decomposition Method
- Boundary Layer Theory
- Numerical Parallel Algorithms and Parallel Computing.
- Bio-Mechanics
- Cryptography
- Image Processing

Vision of the Department

- ✓ To provide high quality education, research and training in Applied Mathematics and in the Multidisciplinary area: "Modelling and Simulation" for solving the complex problems.

Mission of the Department

- ✓ To build strong teaching and research environment for basic and applied research with thrust to defence related problems.
- ✓ To encourage and help the students community to develop mathematical and statistical models and also exploit available tools for solving real life and defence related problems.
- ✓ To become a premier department in the country in the area of "Modelling and Simulation" and applications of mathematics.
- ✓ To provide high quality education, research and customised training in the area of "Modelling and Simulation" for

DRDO Scientists, Service Officers, DPSU and other civilian community.

Programme Educational Objectives

- ✓ The department of Applied Mathematics is committed to impart knowledge related to Modelling & Simulation and applied mathematical techniques to students and service officers to obtain realistic and reasonable solutions for real world and defence related problems to meet the challenges of current and future requirements of nation.
- ✓ Being an interdisciplinary programme, such knowledge can help to solve the problem holistically and to achieve successful career and professional accomplishment.
- ✓ To inculcate positive attitude, professional ethics, effective communication and interpersonal skills which would facilitate them to succeed in the chosen profession exhibiting creativity and innovation through research and development both as team member and as well as leader.

Programme Outcomes (POs)

- ✓ The department imparts higher education and training in the field of modelling and simulation meeting the defence, industries and academic requirement of the country.
- ✓ Various courses offered under his programme help to develop various mathematical models cutting across the boundaries and to understand simulation techniques.
- ✓ After providing the appropriate training in computation and simulation methods and imparting knowledge on contemporary issues, students are well equipped to tackle challenges in the related field.
- ✓ This is a unique capability which helps the students to establish themselves as a successful professional.
- ✓ An ability to function on multidisciplinary teams involving interpersonal skills.
- ✓ An ability to identify, formulate and solve engineering problems of multidisciplinary nature

Organization of M.Techprogramme:

This programme is of four-semester duration. In first and second semester have six courses along with practical component of each course. The respective course instructor will give assignemts / practical problems from the course component and these will be solved in Modelling and Simulation Lab. The practice problems can be solved by using Advanced Data stuructures (C / C++) / MATLAB / MATHEMATICA / Simula8 / Maplesim / SPSS / R / Extend Sim. . .etc., All these softwares are licensed version and available in the department.

In the first semester all courses are compulsory. But in the second semester 2 courses are compulsory and there is an option to choose 4 elective courses, out of which two elective courses must be chosen from the department only and rest of the two elective courses can be chosen from either department or inter department courses. In each of the course component, there will be three tests and a final semester examination of every course. Half yearly evaluation of the project takes place at the end of the third semester. After the second semester, scholarship students are encouraged do a summer internship for about one and half months at their place of choice where as the sponsored category students are encouraged to identify their project work related to their field (labs) to have collaboration a with DIAT.The third and fourthesemester will have only dissertation phase (work) – 1, and dissertation phase (work) – 2(this is in continuation of dissertation phase (work) – 1) respectively. The department faculty will encourage and help to students to take their projects from DRDO labs / premier institutes or as per student's choice. This will be entirely based student's own arrangements and expenses. The department will not sponsor for this; except official arrangements, like issuing no-objection certificate etc. At the end of the final semester he/she submits a thesis and makes a presentation about the project, which is evaluated by the Internal and External examiners. No credits will be counted for attending an audit course.

Eligibility Criteria for Admission to join in this programme

M.Tech Modelling & Simulation	The candidate must have a Valid GATE Score and marks / CPI (Cumulative Performance Index), referred to in subsequent section, implies a minimum of 55% marks/SPI of 5.5 (on a 10-point scale) as long as it is at least seven percent higher than the minimum pass marks/CPI froma recognized Institute / University in Bachelor's Degree in Engineering / Technology OR MSc / MS degree in CS / IT / Mathematics / Physics / Electronics / Statisstics /O.R / Computer Science Provided 1) Mathematics is one of the subject at the graduate level and 2) Knowledge in computer programming is desirable .

Semester I:

Sl. No.	Course Code	Course Name	Credits		Total Credits (*)
			L	T / P	
1.	AM 601	Advanced Numerical Methods	3	1	4
2.	AM 602	Mathematical Modelling & System Analysis	3	1	4
3.	AM 603	Advanced Optimization Techniques	3	1	4
4.	AM 604	Advanced Statistical Techniques	3	1	4
5.	AM 605	Computer Graphics	3	1	4
6.	AM 606	Mathematical Methods	3	1	4
		Total	**18**	**6**	**24**

Semester II:

Sl. No.	Course Code	Course Name	Credits		Total Credits (*)
			L	T / P	
1.	AM 621	Advanced Modelling Techniques	3	1	4
2.	AM 622	Simulation of Linear and Nonlinear Systems	3	1	4
3.		Elective I [From Department(AM)]	3	1	4
4.		Elective II [From Department(AM)]	3	1	4
5.		Elective III	3	1	4
6.		Elective IV	3	1	4
		Total	**18**	**6**	**24**

Semester III:

Sl. No.	Course Code	Course Name	Credits		Total Credits (*)
			L	T / P	
1.	AM 651	M.Tech Dissertation Phase – I	28**		14
		Total	**28**		**14**

Semester IV:

Sl. No.	Course Code	Course Name	Credits		Total Credits (*)
			L	T / P	
1.	AM 652	M.Tech Dissertation Phase - II	28**		14
		Total	**28**		**14**

Note: During summer vacation (4 Weeks), Summer Internship / Industrial Tour will be accepted for all students relevant to the dissertation work especially modeling and Simulation

****Contact Hours / week:-**

- ✓ **One credit in Lecture – L (Theory) / Tutorial (T) mean one contact hour and**
- ✓ **One credit in Practical (P)(Lab session) / Thesis mean Two contact hours)**

List of Electives are given below:

Few of the elective courses are listed below. However, Students are allowed to choose Elective Course(s) from various M. Tech programmes offering by the respective departments which are as per the DIAT PG Course of Study Book / updates of the course curriculum time to time.

Sl. No.	Course Code	Course
Elective I, II, III, IV		
	AM 623	Machine Learning
	AM 624	Tensor Analysis and Engineering Applications
	AM 625	Digital Image Processing
	AM 626	Computational Heat and Mass Transfer
	AM 627	Introduction to Non Newtonian Fluids
	AM 628	Computational Number Theory and Cryptography
	AM 629	Calculus of Variations and Integral Equations
	AM 630	Domain Decomposition Methods
	AM 631	Multigrid Methods
	AM 632	Ballistics
	AM 633	Bio-Mechanics

Course Code	**AM 601**
Course Name	**Advanced Numerical Methods**
L – T – P - C	**03 – 01 - 0 – 4 / 03 – 0 - 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

Course Contents

Solution of Ordinary Differential Equations: Taylor series method – Euler and Modified Euler methods – Runge kutta methods– Multistep methods – Milne"s method – Adams Moulton method.

Boundary Value Problems and Characteristic Value Problems: The shooting method – solution through a set of equations – Derivative boundary conditions – Characteristic value problems – Eigen values of a matrix by Iteration – The power method.

Numerical Solution of Partial Differential Equations- Finite Difference Methods (FDM): (Solutions of Elliptic, Parabolic and Hyperbolic partial differential equations). Representation as a difference equation – Laplace"s equation on a rectangular region – Iterative methods for Laplace equation – The Poisson equation – Derivative boundary conditions – Solving the equation for time-dependent heat flow (i) The Explicit method (ii) The Crank Nicolson method – solving the wave equation by Finite Differences

Finite difference approximations for partial derivatives and finite difference schemes:
Alternate Direction Implicit (ADI) method, Maccormack predictor-corrector method, Lax-Wendroff Method. Dirichlet's problem, Neumann problem, mixed boundary value problem. Higher order compact (HOC) scheme.

Basic concepts of finite volume method (FVM):
Gauss-divergence theorem. Four basic rules. General discretization techniques. Source term linearization and boundary conditions. Over relaxation and under relaxation techniques. Location of control volume faces. Staggered grid concept. Application of FVM. Advantage and disadvantage with the FDM.

Texts / References

1. Numerical Solutions of Differential Equations, 2nd Ed., 1984, M. K. Jain, Wiley Eastern.
2. Numerical Solution of Partial Differential Equations, 3rd Ed., 1986, G.D. Smith, Oxford Univ. Press.
3. Computational Methods for Partial Differential Equations, 2007, M. K. Jain, S. R. K. Iyengar, New Age International.
4. Applied Numerical Analysis, 7th Ed., 2003, Curtis F. Gerald, Patrick O. Wheatley, Pearson Education.
5. Numerical Methods Using MATLAB, 4th Ed., 2004, John H. Mathews, Kurtis D. Fink, Pearson Education.
6. An Introduction to Computational Fluid Dynamics - The Finite Volume Method, 2nd Ed., 2007, H. K. Versteeg, W. Malalasekera, Pearson Education.

Course Code	**AM 602**
Course Name	**Mathematical Modelling and System Analysis**
L – T – P - C	**03 – 01 - 0 – 4 / 03 – 0 - 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

Course Contents

Mathematical Modelling: Introduction to modelling and simulation, Classification of systems into continuous and discrete, Structural characterization of mathematical model and validation techniques.

Modelling Techniques: Dimensional analysis: Concept behind dimensional approach, Buckingham Pi theorem, Models using dimensional approach.

Continuous approach: Models based on physical laws.

Discrete Approach: Models based on discrete approach. Prey - Predator models.

Combat Modelling: Modelling the Lanchester laws with System Dynamics.

System Analysis: The state of a system, mathematical models of continuous linear lumped parameter, time invariant systems, Discrete time systems, Linear approximation of non-linear systems, Topological models of system, Block diagram representation, Signal flow graph, and Mason‘s rule. A generalized approach to modelling. Principles of conservation and continuity and Applications. Basics of simulator technology..

Texts / References

1. Modelling Mathematical Methods & Scientific Computations, 1995, Nicola Bellomo & Luigi Preziosi, CRC Press.
2. Systems Modelling and Analysis, 2003, I.J. Nagrath, M. Gopal, Tata McGraw Hill, New Delhi.
3. Introduction to Mathematical Systems Theory - A behavioural approach, 2nd Ed., 2008, Jan Willen

Polderman, Jan C. Willems, Springer.

4. Introduction to System Dynamics, 1967, J.L. Shearer, A.T. Murphy, H.H. Richardson, Addison& Wesley.
5. Introduction to System Analysis, 1985, T.H. Glisson, McGraw Hill.

Course Code	**AM – 603**
Course Name	**Advanced Optimization Techniques**
L – T – P - C	**03 – 01 - 0 – 4 / 03 – 0 - 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

Course Contents

Linear programming: Simplex method, Two-phase method, Big-M method, duality, Integer linear Programming, Dynamic Programming, Sensitivity analysis.

Assignment problem: Hungarian's algorithm, Degeneracy, applications, unbalanced problems, traveling salesman problem.

Classical optimization techniques: Single variable optimization with and without constraints, multi – variable optimization without constraints, multi – variable optimization with constraints – method of Penalty methods Lagrange multipliers, Kuhn-Tucker conditions.

Numerical methods for optimization: Nelder Mead's Simplex search method, Gradient of a function, Steepest descent method, Newton's method, Conjugate Gradient methods for handling constraints.

Genetic algorithm (GA) : Differences and similarities between conventional and evolutionary algorithms, working principle, reproduction, crossover, mutation, termination criteria, different reproduction and crossover operators, GA for constrained optimization, draw backs of GA

Genetic Programming (GP): Principles of genetic programming, terminal sets, functional sets, differences between GA & GP, random population generation, solving differential equations using GP.

CPM/PERT: Simulation of CPM/PERT network, Analysis of an activity network, Simulation of inventory system and manufacturing system

Texts / References

1. Operations Research: An Introduction, 9th Ed., 2010, Taha, H.A., Prentice Hall of India.
2. Optimization Theory and Applications, 2nd Ed., 1984, S.S. Rao, Wieley Eastern Ltd.
3. Engineering Optimization: Theory and Practice, 4th Ed., 2009, S.S. Rao, Wieley Eastern Ltd.
4. Optimization: Theory and Practice, 2004, MC Joshi, KM Moudgalya, Narosa.
5. Introduction to Optimization, 1988, Beale, John Wiley.
6. Optimal design – Jasbir Arora, Mc Graw Hill (International) Publishers
7. Optimization for Engineering Design – Kalyanmoy Deb, PHI Publishers
8. Genetic algorithms in Search, Optimization, and Machine learning – D.E.Goldberg, Addison Wesley Publishers

9. Genetic Programming- Koza
10. A Field Guide to Genetic Programming, Riccardo Poli, William B. Langdon, Nicholas F. McPhee
11. Genetic Programming Theory and Practice by Rick Riolo, Bill Worzel, Kluwer Academic Publishers
12. Genetic Programming: An Introduction, Wolfgang Banzhaf, Peter Nordin, Robert E. Keller, Frank D. Francone, Morgan Kaufmann Publishers
13. Multi objective Genetic algorithms - Kalyanmoy Deb, PHI Publisher
14. Numerical Methods and Optimization, Hari Arora, S.K. Kataria & Sons
15. Numerical Methods and Optimization: A Consumer Guide, Eric Walter, Springer

Course Code	**AM 604**
Course Name	**Advanced Statistical Techniques**
L – T – P - C	**03 – 01 - 0 – 4 / 03 – 0 - 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

Course Contents

Probability and Probability Distributions: Basic concepts of Probability , Discrete Probability Distributions (Binomial, Poisson etc.), Continuous Probability Distributions (Normal, Exponential, Weibull etc.).

Inferential Statistics: Theory of Estimation, Sampling Distribution, Tests of Hypothesis (one sample t, two sample t etc.), Chi Square Test.

Introduction to Statistical modelling.

Regression modeling for Normal response and quantitative explanatory: Variables, Simple and Multiple regressions, Model building and validation Comparison of regressions.

Stochastic process: Basic idea of random processes, Stationary, Markov processes, Markov chains and applications, Introduction to ergodicity.

Introduction to Design and Analysis of Experiments: Need for conducting Experiments, Applications of experiments, Basic Principles of Experiments, Road Map to conduct efficient experiments Terminologies associated with experiments.

Texts / References

1. Stochastic Process, 3rd Ed., 2010, J. Medhi, New Age Science Ltd.
2. Design and Analysis of Experiments, 8th Ed., 2012, Douglas C. Montgomery, Wiley.
3. Introduction to probability and statistics for engineers and scientists, 4th Ed., 2009, Ross S M, Acdemic Press.
4. An Introduction to Probability Theory and its Application, 3rd Ed., 2012, William Feller, John Wiley India Pvt. Ltd.
5. All of Statistics: A Concise Course in Statistical Inference, 2003, Larry Wasserman, Springer.
6. Introduction to Statistical Modelling, 2010, W. J. Krzanowski, Oxford university press.
7. Schaum‘s outlines Probability and statistics, 4th Ed., 2013, Murray R. Speigel, John Schiller, R Alu

Srinivasan, Tata McGraw Hill.

Course Code	**AM 605 Computer Graphics**
Course Name	**Computer Graphics**
L – T – P - C	**03 – 01 - 0 – 4 / 03 – 0 - 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

Course Contents

Introduction: Application areas of Computer Graphics, overview of graphics systems, video-display devices, raster-scan systems, random scan systems, graphics monitors and work stations and input devices

Output primitives: Points and lines, line drawing algorithms, mid-point circle and ellipse algorithms. Filled area primitives: Scan line polygon fill algorithm, boundary-fill and flood-fill algorithms.

2-D Geometrical transforms: Translation, scaling, rotation, reflection and shear transformations, matrix representations and homogeneous coordinates, composite transforms, transformations between coordinate systems.

2-D Viewing: The viewing pipeline, viewing coordinate reference frame, window to view-port coordinate transformation, viewing functions, Cohen-Sutherland and Cyrus-beck line clipping algorithms, Sutherland –Hodgman polygon clipping algorithm.

3-D Object representation: Polygon surfaces, quadric surfaces, spline representation, Hermite curve, Bezier curve and B-spline curves, Bezier and B-spline surfaces. Basic illumination models, polygon rendering methods.

3-D Geometric transformations: Translation, rotation, scaling, reflection and shear transformations, composite transformations, 3-D viewing: Viewing pipeline, viewing coordinates, view volume and general projection transforms and clipping.

Visible surface detection methods: Classification, back-face detection, depth-buffer, scan-line, depth sorting, BSP-tree methods, area sub-division and octree methods

Computer animation: Design of animation sequence, general computer animation functions, raster animation, computer animation languages, key frame systems, motion specifications

Texts / References

1. Computer Graphics, Donald Hearn and M. Pauline Baker, Pearson education, C version.
2. Computer Graphics Principles & practice, second edition in C, Foley, VanDam, Feiner and Hughes, Pearson Education.
3. Computer Graphics Second edition, Zhigand xiang, Roy Plastock, Schaum's outlines, Tata Mc Graw hill edition.
4. Procedural elements for Computer Graphics, David F Rogers, Tata Mc Graw hill, 2nd edition.
5. Principles of Interactive Computer Graphics, Neuman and Sproul, TMH.
6. Principles of Computer Graphics, Shalini, Govil-Pai, Springer.
7. Computer Graphics, with OpenGL Hearn and Baker, - Pearson
8. Computer Graphics, Sinha & Udai, - TMH

Course Code	**AM 606 Mathematical Method**
Course Name	**Mathematical Methods**
L – T – P - C	**03 – 01 - 0 – 4 / 03 – 0 - 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

Course Contents

Differential Equations: Review of solution methods for first order as well as second and Higher order equations, Power Series methods with properties of Bessel functions and Legendre polynomials. **Applications:** Orthogonal Trajectories, Population Growth and Decay, Newton's Law of Cooling, Free Falling Bodies. Simple Harmonic Motion, Damped Motion, Forced Motion, Other Applications in Electronics and Pendulum Problem.

Linear Algebra: General (real) vector spaces, Subspaces, Linear independence, Dimension, Norms, Orthogonal bases and Gram-Schmidt orthogonalization, Linear transformation, Kernel and range, Inverse transformations, Matrices of linear transformations, Change of basis, Similarity , Eigen values and eigen vectors, Diagonalization, Orthogonal diagonalization and symmetric matrices, Quadratic forms.

Transform Techniques: Over View of Laplace Transforms – Inverse Laplace Transforms – Fourier transform: Flourier integral formula – Fourier transform – Inversion theorem for complex Fourier transform – Fourier Sine and Consine transforms – Inversion formulae – Finite Fourier sine and Cosine Transform – Inversion formulae – Application of transform techniqes to solutions of differential equations, integral equations and boundary value problems. Wavelets – The Haar wavelets – A wavelets expansion – Multiresolution analysis with Haar Wavelets – General construction of wavelets and multiresolution analysis - Shannon wavelets.

Texts / References

1. Advanced Engineering Mathematics, 10^{th} Ed, 2005, Erwin Kreyszig Wiley Eastern.
2. Linear Algebra and its Applications, 4^{th} Ed., 2008, Gilbert-Strang, Academic press.
3. Applied Linear Algebra & Matrix Analysis, 2007, Thomas S Shores, Springer.
4. Advanced Engineering Mathematics, Peter V. O'Neil Thomson Brooks /Cole
5. Ordinary Differential Equations by Deo and Raghavendra
6. Fourier analysis with Applications of boundary value problems schaum series.
7. Integral Transforms by Goyal and Gupta.

Course Code	**AM 607 Mathematics for Engineers**
Course Name	**Mathematics for Engineers**
L – T – P - C	**03 – 01 - 0 – 4 / 03 – 0 - 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

Course Contents

I. <u>Elements of Probability and Statistics:</u>

Basic concepts of Probability, Discrete Probability Distributions (Binomial, Poisson etc.), Continuous Probability Distributions (Normal, Exponential, etc.,).

II. <u>Components of Operations Research:</u>

Introduction to Operations Research, Linear programming (Simplex Method, Revised Simplex Method, Dual simplex, Duality theory), Transportation Models.

III. <u>Linear Algebra:</u>

General (real) vector spaces, Subspaces, Linear Independence of Vectors, Basis and Dimension, Linear Transformations, Span, Norms, Orthogonal basis and Gram-Schmidt Orthogonalization.

IV. <u>Ordinary Differential Equations:</u>

Review of solution methods for first order as well as second order equations, Power Series methods. Higher Order Linear Equations, Boundary Value Problems for Second Order Equations.

V. <u>Transform Techniques :</u>

Overview of Laplace transforms, Fourier Transforms, Z transform.

VI. <u>Numerical Methods and P.D.E.:</u>

Interpolation: Review of Lagrange interpolation techniques, Newton interpolation, piecewise linear, cubic splines. Solution of PDE: Parabolic, Hyperbolic and Elliptic Equations using finite difference methods

Texts / References

1. Advanced Engineering Mathematics, 11th Ed, 2010, Erwin Kreyszig, Wiley Eastern.
2. Linear Algebra and its Applications, 4th Ed., 2008, Gilbert Strang, Academic Press.
3. Numerical Methods for Scientists and Engineers, Joe D. Hoffman, Marcel Dekker Inc.
4. Numerical Methods for Engineers, Sixth Edition, Steven Chapra and Raymond Canale, McGraw-Hill Education
5. Elements of Numerical Analysis, 2nd Edition, Radhey S. Gupta, Cambridge University Press
6. Numerical Solutions of Partial Differential Equations: An Introduction, 2nd Ed., 2005, K. W. Morton, D. F. Mayers, Cambridge University Press.
7. Operations Research: An Introduction, 9th Ed., 2010, Taha, H.A., Prentice Hall of India.
8. Optimization Theory and Applications, 2nd Ed., 1984, S.S. Rao, Wieley Eastern Ltd.
9. Introduction to probability and statistics for engineers and scientists, 4th Ed., 2009, Ross S M, Acdemic Press.
10. An Introduction to Probability Theory and its Application, 3rd Ed., 2012, William Feller, John Wiley India Pvt. Ltd.
11. Differential Equations and Dynamical Systems, Texts in Applied Mathematics, L. Perko, 3rd Ed., Vol.

7, 2006, Springer Verlag, New York.
12. .S. Gupta.. Calculus of Variation, Prentice Hall of India Pvt. Ltd.

Course Code	**AM 621**
Course Name	**Advanced Modelling Techniques**
L – T – P - C	**03 – 01 - 0 – 4 / 03 – 0 - 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

Course Contents

Fuzzy logic: Basic concepts of fuzzy set, Operation on fuzzy sets, Fuzzy numbers Fuzzy relation, Fuzzification, Fuzzy logic as generalization of two valued logic, Fuzzy system, fuzzy control, fuzzy clustering.

Artificial Neural Networks – Introduction, Neural network representation, Appropriate problems for neural network learning, Perceptions, Multilayer networks and the back propagation algorithm, Remarks on the back propagation algorithm, An illustrative example face recognition Advanced topics in artificial neural networks

Dynamics of Chaos: Introduction to chaos, Lorenz system, Lorenz attractor, Dimension of chaotic attractor, applications in communications.

Fractals: Introduction to fractals, Types of fractal dimensions, Generation of fractals by mathematical approach, Julia and Mandelbrot sets.

Texts / References

1. Fuzzy Logic with Engineering Applications, 2009, Timothy J Ross, Wiley.
2. Neural Computing: An Introduction, 2010, R. Beale, T. Jackson, Adam Hilger, CRC Press.
3. Neural fuzzy systems: A Neurofuzzy Synergism to Intelligent Systems, 1996, Chin- Teng Lin and C.S.G. Lee, Prentice Hall International, INC.
4. Encounter With Chaos, 1992, Denny Gulick , McGraw Hill Inc.

Course Code	**AM 622**
Course Name	**Simulation of Linear and Nonlinear Systems**
L – T – P - C	**03 – 01 - 0 – 4 / 03 – 0 - 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

Course Contents

Simulation of single server and multiple server queuing system. Design (component & organisation) of a simulation experiment. Rational selection of input distribution. Output data analysis. Variance reduction techniques, Model validation. Discrete event systems, Time advance mechanism, Simulation, Monte Carlo

& Stochastic Simulation Generation of random numbers, Pseudo random numbers, Test for random number simulation of probability distribution. Discrete event simulation: simulation of single server and multiple server queuing system. Concept of systems, Classification of systems, General Properties of Linear and nonlinear systems. Periodic orbits, Poincare Bendixson criterion, limit cycle, bifurcation, Lyapunov Stability, basic stability and instability theorems, uniform stability, asymptotic stability, exponential stability
Texts / References
1. An Introduction to Mathematical Control Theory, 1990, S. Barnett and R. G. Cameron, Oxford University Press. 2. Nonlinear Systems, 3rd Ed., 2003, H.K. Khalil, Prentice Hall. 3. Applied Nonlinear Control, 1991, J.J.E. Slotine, W. Li, Prentice Hall 4. Simulation Modeling & Analysis, 2008, Law A.M., Tata McGraw Hill. 5. System Modelling and Computer Simulation, 1996, Kheir N.A, Marcell Dekker. 6. Discrete-Event System Simulation, 5th Ed., 2009, Jerry Banks, John Carson, Barry L. Nelson, David Nicol, Prentice Hall 5. Operations Research: An Introduction, 2002, Taha H.A, Prentice Hall.

Course Code	**AM 623**
Course Name	**Machine Learning**
L – T – P - C	**03 – 01 - 0 – 4 / 03 – 0 - 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

Course Contents

Introduction - Well-posed learning problems, Designing a learning system, Perspectives and issues in machine learning

Concept learning and the general to specific ordering – Introduction, A concept learning task, Concept learning as search, Find-S: finding a maximally specific hypothesis, Version spaces and the candidate elimination algorithm, Remarks on version spaces and candidate elimination, Inductive bias

Decision Tree learning – Introduction, Decision tree representation, Appropriate problems for decision tree learning, The basic decision tree learning algorithm, Hypothesis space search in decision tree learning, Inductive bias in decision tree learning, Issues in decision tree learning

Evaluation Hypotheses – Motivation, Estimation hypothesis accuracy, Basics of sampling theory, A general approach for deriving confidence intervals, Difference in error of two hypotheses, Comparing learning algorithms

Bayesian learning – Introduction, Bayes theorem, Bayes theorem and concept learning, Maximum likelihood and least squared error hypotheses, Maximum likelihood hypotheses for predicting probabilities, Minimum description length principle, Bayes optimal classifier, Gibs algorithm, Naïve Bayes classifier, An example learning to classify text, Bayesian belief networks The EM algorithm

Computational learning theory – Introduction, Probability learning an approximately correct hypothesis, Sample complexity for Finite Hypothesis Space, Sample Complexity for infinite Hypothesis Spaces, The mistake bound model of learning - **Instance-Based Learning-** Introduction, k -Nearest Neighbour Learning, Locally Weighted Regression, Radial Basis Functions, Case-Based Reasoning, Remarks on Lazy and Eager Learning

Genetic Algorithms – Motivation, Genetic Algorithms, An illustrative Example, Hypothesis Space Search, Genetic Programming, Models of Evolution and Learning, Parallelizing Genetic Algorithms

Learning Sets of Rules – Introduction, Sequential Covering Algorithms, Learning Rule Sets: Summary, Learning First Order Rules, Learning Sets of First Order Rules: FOIL, Induction as Inverted Deduction, Inverting Resolution

Analytical Learning - Introduction, Learning with Perfect Domain Theories: Prolog-EBG Remarks on Explanation-Based Learning, Explanation-Based Learning of Search Control Knowledge

Combining Inductive and Analytical Learning – Motivation, Inductive-Analytical Approaches to Learning, Using Prior Knowledge to Initialize the Hypothesis, Using Prior Knowledge to Alter the Search Objective, Using Prior Knowledge to Augment Search Operators,

Reinforcement Learning – Introduction, the Learning Task, Q Learning, Non-Deterministic, Rewards and Actions, Temporal Difference Learning, Generalizing from Examples, Relationship to Dynamic Programming.

Texts / References

1. Machine Learning – Tom M. Mitchell, - MGH
2. Machine Learning: An Algorithmic Perspective, Stephen Marsland, Taylor & Francis (CRC)
3. Machine Learning Methods in the Environmental Sciences, Neural Networks, William W Hsieh, Cambridge Univ Press.
4. Richard o. Duda, Peter E. Hart and David G. Stork, pattern classification, John Wiley & Sons Inc., 2001.
6. Chris Bishop, Neural Networks for Pattern Recognition, Oxford University Press, 1995

Course Code	**AM 624**
Course Name	**Tensor Analysis and Engineering Applications**
L – T – P - C	**03 – 01 - 0 – 4 / 03 – 0 - 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

Course Contents

Definition and algebra of tensors. Summation convention – Contravariant and covaraiant vectors – Contraction of tensors – Inner product – Quotient law – Metric tensor – Chrirstoffel symbols – Covariant differentiation – Gradient, divergence and curl. Dyadic representation in Cartesian and general components. Calculus of tensor fields in curvilinear coordinates. Derivation and application of the basic equations of heat conduction, rigid body mechanics, elasticity, fluid mechanics & electromagnetism in tensor form.

Texts / References

1. Tensor Calculus - Barry Spain ., Radha Publishing House.
2. Mathematical Methods in Physics & Engg.,- John W.Dettman., Mc-Grawhill.
3. Tensor Calculus – U.C.De, Absos Ali Shaikh & Joydeep Sengupta., Narosa Publications.
4. Tensor Analysis with Application in Mechanics – Leonid.P.Levedev, Michael.J.Cloud Victoria eremeyev; World Scientific Publication.
5. Applications of Tensor Analysis – A.J.MeConnell, Dover Publications.
7. Tensor Analysis with Applications – Jafer Ahsan, Annamaya Publications

Course Code	**AM 625**
Course Name	**Digital Images Processing**
L – T – P - C	**03 – 01 - 0 – 4 / 03 – 0 - 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

Course Contents

Digital Image Fundamentals: Introduction – Origin –Steps in Digital Image Processing – Components; Elements of Visual Perception – Light and Electromagnetic Spectrum – Image Sensing and Acquisition – Image Sampling and Quantization – Relationships between pixels.

Image Enhancement: Spatial Domain: Gray level transformations – Histogram processing – Basics of Spatial Filtering–Smoothing and Sharpening Spatial Filtering – Frequency Domain: Introduction to Fourier Transform – Smoothing and Sharpening frequency domain filters – Ideal, Butterworth and Gaussian filters.

Image Restoration: Noise models – Mean filters – Order Statistics – Adaptive filters – Band reject – Band pass – Notch – Optimum notch filtering – Inverse Filtering – Constrained Least Square Filtering – Wiener filtering.

Morphological image processing: Dilation, Erosion, Opening, Closing, Applications to; Boundary extraction, Region filling, Extraction of connected components.

Image Compression: Fundamentals – Image Compression models – Error Free Compression – Variable Length Coding –Bit – Plane Coding – Lossless Predictive Coding – Lossy Compression – Lossy Predictive Coding –Wavelet Coding – Compression Standards – JPEG2000.

Image Segmentation and Representation: Segmentation – Detection of Discontinuities – Edge Linking and Boundary detection – Region based segmentation; Representation – Boundary descriptors – Simple Descriptors – Shape numbers –Regional descriptors – Simple and Topological Descriptors – Introduction to Image Processing Toolbox – Practice of Image Processing Toolbox – Case studies–Various Image Processing Techniques.

Object recognition: Decision-theoretic methods.

Texts / References

1. Digital Image Processing, 3rd Ed., 2007, R. C. Gonzalez, Richard E. Woods, Prentice Hall.
2. Digital Image Processing Using MATLAB, 2nd Ed., 2009, R. C. Gonzalez, Richard E. Woods, Steven L. Eddins, Gatesmark Publishing.
3. Digital Picture Processing, 2nd Ed., 1982, A. Rosenfeld, A. C. Kak, Academic Press.
4. Fundamentals of Digital Image Processing, 1st Ed., 1989, A.K. Jain, Prentice Hall of India.
5. Pattern Classification and Scene Analysis, 1973, R. O. Duda, P. E. Hart, John Wiley.
6. Pattern Recognition, Applications to Large Data-Set Problems, 1984, Sing-Tze Bow, Marcel Dekker.

Course Code	**AM 626**
Course Name	**Computational Heat and Mass Transfer**
L – T – P - C	**03 – 01 - 0 – 4 / 03 – 0 - 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

Course Contents

Philosophy of Computational Fluid Dynamics: Introduction to CFD, CFD- a research tool, CFD- a design tool, Applications and Advantages of CFD, The basic governing fluid flow equations in differential form, Models of Fluid flow, Concept of Substantial derivative, Navier-Stoke's model and Euler's model equations.

Convective Heat Transfer:

Introduction to convection, review of conservation equations - Forced convection in laminar flow - Exact and approximate solutions of Boundary layer energy equation for plane isothermal plate in longitudinal flow - problems. Forced convection heat transfer in laminar tube flow - forced convection in turbulent flow – Internal Flows-Correlations-Problems. Approximate analysis of laminar free convective heat transfer on a vertical plate-external flows-correlations-problems.

Convective Mass Transfer

Definitions of concentration and velocities relevant to mass transfer, Fick's law, species conservation equation in different forms. Steady state diffusion in dilute solutions in stationary media, transient diffusion in dilute solutions in stationary media, one dimensional non dilute diffusion in gases with one component stationary. Convective mass transfer - governing equations-forced diffusion from flat plate-Dimension less correlation's for mass transfer. Simultaneous heat and mass transfer - analogy between heat, mass and momentum transfer

Finite Element Method Technique: Formulation Techniques: Methodology, Engineering problems and governing differential equations, finite elements, Variational methods-potential energy method, Raleigh

Ritz method, strong and weak forms, Galerkin and weighted residual methods, Piecewise Defined Shape functions, Essential and natural boundary conditions. One-dimensional finite element methods: Bar elements. Element matrices, assembling of global stiffness matrix, Application of boundary conditions, Quadratic Element, Implementation of the FEM - The Solution Procedure. **Finite Element Method Techniques in Heat & Mass Transfer problems:** One-dimensional, conduction and convection problems examples:. Two dimensional problems: CST, LST, four noded and eight nodded rectangular elements, Lagrange basis for triangles and rectangles, serendipity interpolation functions. Axisymmetric Problems: Axisymmetric formulations, Element matrices, boundary conditions. Examples: - two dimensional fin. Isoperimetric formulation: Concepts, sub parametric, super parametric elements, numerical integration.
Texts / References

1. Computational Fluid Dynamics-Basics with applications, 1st Ed., 1995, John D. Anderson: McGraw-Hill Science.
2. An Introduction to Fluid Dynamics, 2010, G. K. Batchelor, Cambridge University Press.
3. Computational Fluid Mechanics and Heat Transfer, 3rd Ed., 2011, Richard H. Pletcher, John C. Tannehill, Dale Anderson, Taylor & Francis.
4. Computational Fluid Dynamics: A Practical Approach, 1st Ed., 2008, Jiyuan Tu, Guan Heng Yeoh, Chaoqun Liu, Butterworth-Heinemann.
5. Computational Methods for Fluid Dynamics, 3rd Ed., 2013, J. H. Ferziger, M. Peric, Springer.
6. Convection in Porous Media, 4^{th} Ed., 2013, Donald A. Nield, Adrian Bejan, Springer.
7. Convective Heat and Mass Transfer, 1^{st} Ed., 2011, S. Mostafa Ghiaasiaan, Cambridge University Press.
8. Fundamentals of Heat & Mass Transfer by Thirumaleshwar, Pearson
9. Conduction Heat transfer, Poulikakos, Prentice Hall, 1994.
10. Analytical methods in Conduction Heat Transfer, G.E. Mayers, McGraw Hill, 1971.
11. Convective Heat and Mass Transfer, Kays W M and Crawford M E, McGraw Hill Int Edition, 3rd edition, 1993.
12. Introduction to Convective Mass Transfer, Spalding D B, McGraw Hill, 1963.

Course Code	**AM 627**
Course Name	**Introduction to Non-Newtonian Fluids**
L – T – P - C	**03 – 01 - 0 – 4 / 03 – 0 - 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**
Course Contents	
Kinematics of Fluids Flow: Introduction, Velocity Gradient Tensor, Rate of Deformation Tensor,	

Analysis of Strain Rates, Spin Tensor, Curvature-Twist Rate Tensor, Objective Tensors, Balance of Mass.

Governing Equations: Introduction, Measure of Mechanical Interactions, Euler's Laws of Motion, Stress and Couple Stress Vectors, Stress and Couple Stress Tensors, Cauchy's Laws of Motion, Analysis of Stress, Energy Balance Equations, Entropy Inequality.

Couple Stress Fluids: Introduction, Constitutive Equations, Equations of Motion, Boundary Conditions, Steady Flow between Parallel Plates, Steady Dimensional Flow between Two Co-axial Cylinders, Poiseuille Flow through Circular Pipes, Creeping Flow Past a Sphere, Some Time- Dependent Flows, Hydromagnetic Channel Flows.

Micro Fluids: Introduction, Description of Micro motion, Kinematics of Deformation, Conservation of Mass, Balance of Moments, Micro Inertia Moments, Balance of Energy, Entropy Inequality, Constitutive Equations for Micro Fluids, Linear Theory of Micro Fluids, Equations of Motions.

Micropolar Fluids: Introduction, Skew-symmetric of the Gyration Tensor and Micro Isotropy, Micropolar Fluids, Thermodynamics of Micropolar Fluids, Equations of Motion, Boundary and Initial Conditions, Two Limiting Cases, Steady Flow between Parallel Plates, Steady Couette Flow between Two Co-axial Cylinders, Pipe Poiseuille Flow, Micropolar Fluids with Stretch

Texts / References

1. An Introduction to Fluid Dynamics, 1976, R.K.Rathy, Oxford & IBH Publishing.
2. Theory of Fluids with Microstructure – An Introduction, 1984, Vijay Kumar Stokes, Springer – Verlag
3. Micropolar Fluids Theory and Applications, 1999, Grzegorz Lukaszewicz, Birkhauser Boston.
4. Fluid Dynamics, 3rd Ed., 2004, William F. Hughes, John A. Brighton, Tata McGraw- Hill.

Course Code	**AM 628**
Course Name	**Computational Number Theory and Cryptography**
L – T – P - C	**03 – 01 - 0 – 4 / 03 – 0 - 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

Course Contents

Introduction: Attacks, Services and Mechanisms, Security attacks, Security services, A Model for Internetwork security. Classical Techniques: Conventional Encryption model, Steganography, Conventional Encryption Principles, Conventional encryption algorithms, cipher block modes of operation, location of encryption devices.

Number Theory:

Divisibility: Representations of Integers, Computer Operations with Integers, Complexity of Integer Operations, Divisibility, Prime Numbers, The Fundamental Theorem of Arithmetic, Sieve of Eratosthenes, The Distribution of Primes, Greatest Common Divisor, Euclidean Algorithm, Mersenne Numbers, Fermat Numbers, Perfect numbers

Congruence: Congruences, Congruence Applications, Linear Congruences, The Chinese Remainder

Theorem, Theorems of Fermat and Euler- Fermat, Wilson's Theorem, Pseudo Primes, Carmichael Numbers, The Euler Phi-Function, The Sum and Number of Divisors, Quadratic Residue, Quadratic Reciprocity.

Factorization and Primality Testing: Complexity of Number Theoretic Algorithms, Fermat's Factorization, Kraitchik's Improvement, Pollard Rho Algorithm, Legendre and Jacobi Symbols, Computing Legendre symbols, Primitive Roots, Pseudo Primality Testing, Miller-Rabin Algorithm, Quadratic Reciprocity Law

Finite fields: Groups, Fields, Finite Fields, Arithmetic in Finite Field, Finding Multiplicative Inverses in finite fields, Binary Fields and their application in Cryptosystems, Primitive roots.

Cryptography: Introduction to Cryptosystems, Classical Ciphers, Cryptanalysis of Classical ciphers, LFSR based stream ciphers. Shannon's Theory, Public Key Cryptography, RSA Cryptosystem, Diffie-Helman Key Exchange, Rabin Cryptosystem, Knapsack Ciphers, Digital Signature, Secret Sharing, ElGamal Cryptosystem, Elliptic Curve Cryptography.

Elliptic Curve Cryptography: Introduction to Elliptic Curves, Geometry of Elliptic curves over Reals, Weierstrass Normal form, Point at infinity, Elliptic Curves over Finite fields, Group structure, Discrete Log problem for Elliptic curves, Factorization using Elliptic Curve, Advantage of Elliptic Curve Cryptography over other Public Key Cryptosystems.

Texts / References

1. N. Koblitz, A Course in Number Theory and Cryptography, Springer 2006.
2. I. Niven, H.S. Zuckerman, H.L. Montgomery, An Introduction to theory of numbers, John Wiley & Sons, Inc 2006.
3. L. C. Washington, Elliptic curves: number theory and cryptography, Chapman & Hall/CRC, 2003.
4. J. Silverman and J. Tate, Rational Points on Elliptic Curves, Springer-Verlag, 2005.
5. D. Hankerson, A. Menezes and S. Vanstone, Guide to elliptic curve cryptography, Springer-Verlag, 2004.
6. J. Pipher, J. Hoffstein and J. H. Silverman , An Introduction to Mathematical Cryptography, Springer-Verlag, 2008.
7. G.A. Jones and J.M. Jones, Elementary Number Theory, Springer-Verlag, 1998.
8. R.A. Mollin, An Introduction to Cryptography, Chapman & Hall, 2001.
9. Song Y. Yan: Number Theory for Computing, Springer-Verlag, Second Edition,2002.
10. T. H. Cormen, C. E. Leiserson, and R. L. Rivest: Introduction to Algorithms, Second Edition, Prentice Hall of India, 1994.
11. K. Rosen: Elementary Theory of Numbers, Fifth Edition, Addison Wesley, 2004.
12. D. M. Bressoud: Factorization and Primality Testing, Springer-Verlag, 1989.

Course Code	**AM 629**
Course Name	**Calculus of Variations and Integral Equations**

L – T – P - C	**03 – 01 - 0 – 4 / 03 – 0 - 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

Course Contents

Linear integral equations, Some basic identities, Initial value problems reduced to Volterra integral equations, Methods of successive substitution and successive approximation to solve Volterra integral equations of second kind, Iterated kernels and Neumann series for Volterra equations. Resolvent kernel as a series in, Laplace transforms method for a difference kernel, Solution of a Volterra integral equation of the first kind.

Boundary value problems reduced to Fredholm integral equations, Methods of successive approximation and successive substitution to solve Fredholm equations of second kind, Iterated kernels and Neumann series for Fredholm equations. Resolvent kernel as a sum of series. Fredholm Resolvent kernel as a ratio of two series. Fredholm equations with separable kernels, Approximation of a kernel by a separable kernel, Fredholm Alternative, Non homogenous Fredholm equations with degenerate kernels.

Green's function, Use of method of variation of parameters to construct the Green's function for a non-homogeneous linear second order boundary value problem, Basic four properties of the Green's function, Orthogonal series representation of Green's function, Alternate procedure for construction of the Green's function by using its basic four properties. Reduction of a boundary value problem to a Fredholm integral equation with kernel as Green's function. Hilbert-Schmidt theory for symmetric kernels.

Motivating problems of calculus of variations, Shortest distance, Minimum surface of revolution, Branchistochrone problem, Isoperimetric problem, Geodesic. Fundamental lemma of calculus of variations, Euler's equation for one dependant function and its generalization to 'n' dependant functions and to higher order derivatives, Conditional extremum under geometric constraints and under integral constraints.

Texts / References

1. A.J. Jerri. Introduction to Integral Equations with Applications. Wiley-Interscience.
2. R.P. Kanwal. Linear Integral Equations: Theory and Techniques. New York: Academic Press.
3. J.M. Gelfand and S.V. Fomin. Calculus of Variations. Englewood Cliffs: Prentice-Hall, 1963.
4. Weinstock . Calculus of Variations. McGraw-Hall.
5. Abdul-Majid Wazwaz. A First Course in Integral Equations. World Scientific Pub.
6. P. David and S.G. David. Stirling Integral Equations. Cambridge University Press.

Course Code	**AM 630**
Course Name	**Domain Decomposition Methods**
L – T – P - C	**03 – 01 - 0 – 4 / 03 – 0 - 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

Course Contents

The mathematical Foundation of Domain decomposition Methods. Discretised equations and Domain Decomposition Methods. Schur Complement and Iterative Sub-structuring Algorithms. Iterative Domain Decomposition Methods. Time-dependent problems. Multilevel and local grid refinement methods.

Texts / References

1. Domain Decomposition Methods for Partial Differential Equations, 1999, Alfio Quarteroni and Alberto Valli, Clarendon Press, Oxford.
2. The Finite Element Method for Elliptic Problem, 1989, P. G. Ciarlet, North-Holland Publishing Company, Newyork.
3. Domain Decomposition Methods Algorithms and Theory, 2004, A. Toselli and O. Widlund, Springer-Verlag.
7. Domain Decomposition Methods for the Numerical Solution of Partial Differential Equations, 2008, Tarek P.A. Mathew, Springer-Verlag Berlin Heidelberg

Course Code	**AM 631**
Course Name	**Multigrid Methods**
L – T – P - C	**03 – 01 - 0 – 4 / 03 – 0 - 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

Course Contents

Basic concepts, local and global processing, discretization, 1D model problem and its direct and iterative solution, convergence analysis, 2D model problem, classical relaxation methods, error-smoothing by relaxation, grid-refinement algorithm, two-grid and multigrid algorithm, Fourier analysis of convergence, ellipticity and h-ellipticity, nonlinear and anisotropic problems, advanced techniques, algebraic approach, applications.

Texts / References

1. B. Smith, P. Bjorstad, W. Gropp, Domain Decomposition: Parallel Multilevel Methods for Elliptic Partial Differential Equations, Cambridge, 1996.
2. E. Henson, and S. F. McCormick: A Multigrid Tutorial, 2nd ed., SIAM, 2000.
3. U. Trottenberg, C. W. Oosterlee, and A. Schueller: Multigrid, Academic Press, 2001.
4. W. Hackbusch and U. Trottenberg eds.: Multigrid Methods, Springer-Verlag, Berlin, 1982.
4. P. Wesseling: An Introduction to Multigrid Methods, Wiley, Chichester, 1992.
5. W. Hackbusch: Multi-grid Methods and Applications, Springer, Berlin 1985.
6. Brandt: Multi-level Adaptive Solutions to Boundary-Value Problems, Math. Comput, Vol. 31, 333-390, 1977.

Course Code	**AM 632**
Course Name	**Ballistics**
L – T – P - C	**03 – 01 - 0 – 4 / 03 – 0 - 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

Course Contents

Explosives: Explosive compounds and explosive mixtures-classification of explosives: Measurement of various explosive parameters

Internal Ballistics: General introduction –Propellants-Driving Band engraving process, and the resistance to the in–bore motion of a projectile- Heating of gun barrel- Heat conduction in thick walled barrels-Numerical solution for heat conduction- Wear in gun barrels- Prediction of pressure history and muzzle velocity- The internal ballistics of leaking gun.

External Ballistics: Projectile Aerodynamics: General introduction-yaw-The aerodynamic forces and moments acting on a projectile-linearised aerodynamics-centre of pressure and stability-Aerodynamic coefficients-Drag laws-Angular motion of projectiles-Gyroscopic stability-Yawing behaviour-The linearised theory of yawing motion-projectiles with slight configurational asymmetries-projectiles not obeying classical linear theory.

Projectile Transitional Motion: Motion in vacuum-Motion of point mass-Trajectory modelling-constant corrections to the plane-particle trajectory, biases-variable corrections to the plane-particle trajectory, dispersion-the effect of wind.

Terminal Ballistics: Kinetic Energy projectiles: Penetration into resisting medium-Empirical formulae for the prediction of penetration-Analytical models of failure modes-Numerical methods-plate charges.

Design and Defeat of Armour: Introduction –Mechanical property requirements-Armour material Characteristics –Armour structure-stress-strain relationship-Waves in rods-Defeat of armour-Failure

Wound Ballistics: Threshold velocity for penetration of skin, flesh, bones- Nature of wounds on entry, exit-Explosive wounds- Evaluation of injuries caused due to shot gun, rifle, hand guns and country made firearms- Method of measurement of wound ballistic parameters- post mortem and ante- mortem firearm injuries.

Texts / References

1. The Books of Ballistics and Gunnery, 1987, War Office, UK.
2. Modern Exterior Ballistics, 1999, Robert McCoy-Schiffer publishing Ltd.
3. Interior Ballistics, 1951, HMSO publication
4. Terminal Ballistics- A Text Book and atlas of gunshot wounds, Malcom J Dodd, CRC press, Taylor & Francis publications

5. Firearms in criminal investigation and trials, Dr. BR Sharma, 3rd Edition, Universal Law publishing Co. Pvt Ltd.
6. Gunshot wounds- practical aspects of Firearms. Ballistics and Forensic Techniques, Vincent JM DiMaio, Elsevier Science publishing Co. Inc
7. Wound Ballistics and the Scientific Background, Karl G Sellier & Beat P Kneubuehl Elseviour Science publishing Co. Inc.

Course Code	**AM 633**
Course Name	**Bio-Mechanics**
L – T – P - C	**03 – 01 - 0 – 4 / 03 – 0 - 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

Course Contents

Biomechanics, Method of approach, Tools of investigation, Stresses and rates of strain, Constitutive equations, Newtonian viscous fluid, Hookean elastic solid, Viscoelasticity, Biological transport process, Basic momentum, Heat and mass transport concepts. Conservation laws; mass conservation, Momentum conservation, Energy conservation.

Introduction - Continuum Approach - Blood Flow in Heart, Lung, Arteries and Veins: Introduction - The geometry of the circulation system - Field equations and Boundary conditions, Pulsatile Flow in Arteries - Progressive

The Rheological Properties of Blood Bio-fluid dynamics concept, Transport phenomena and the cardiovascular system.

Biofluid mechanics of organ systems, The lungs, The Kidneys and the lever. Micro-circulation, Pressure distribution in micro vessels, Pressure in the intesstitial space, Velocity distribution in micro vessels, The velocity-Hemotocrit relationship, mechanics of flow at very low Reynolds numbers.

Texts / References

1. Biomechanics, Springer-verlag: Y.C.Fung
2. Bio-fluid Dynamics Taylor and Francis: Clement Kluinstreuer
3. Frontier in Mathematical Biology: S.A.Levin
4. Biomathematics: Ricciardi