INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Applied Mathematics and Scientific Computing

Subject Code: AMC-501 **Course Title:** Applied Optimization Techniques

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** PCC

Course Outlines: Introduction to optimization, convex sets, convex functions, mathematical modeling, Linear Programming: Graphical method, Simplex method, Duality in linear programming, sensitivity analysis, dual simplex method, Integer programming problems, mixed integer programming problems, Unconstrained Optimization – Newton-Raphson method, quasi-Newton methods, Conjugate-Gradient method, Steepest–Descent method, Constrained Optimization – Lagrange Method, Generalized reduced gradient method, Penalty function methods, Multi-objective Optimization – Multi objective optimization problems, Pareto front, dominated and non-dominated solutions, classical multi-objective optimization methods like weighted sum approach, e-constrained method.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Applied Mathematics and Scientific Computing

Subject Code: AMC-503 **Course Title**: Stochastic Processes

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** PCC

Course outlines: Review of Probability distributions, Introduction to Stochastic Processes, weakly and strongly stationary processes, moving average and auto regressive processes. Discrete-time Markov Chains, transition probability matrix, Continuous-time Markov Chains, Kolmogorov- Feller differential equations. Brownian Motion, Wiener process as a limit of random walk, process derived from Brownian motion.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Applied Mathematics and Scientific Computing

Subject Code: AMC-505 **Course Title**: Numerical Linear Algebra

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** PCC

Course outlines: Review of diagonalizability of matrices, Generalized eigenvalues, matrix norms, condition number. Singular value decomposition (SVD), least squares problems, Low rank approximation, Pseudo inverse, sensitivity analysis for SVD. Gershgorin's theorem, Rayleigh principle, Courant–Fischer min-max principle, Sylvester's law of inertia, Bauer-Fike theorem, Sensitivity analysis for eigenvalues, The power method, inverse iteration by von Wielandt, Jacobi method, Householder reduction to Hessenberg form, QR algorithm. Introduction to Krylov subspace methods - Arnoldi’s method, GMRES method, Conjugate gradient algorithm, Lanczos algorithm.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Applied Mathematics and Scientific Computing

Subject Code: AMC-507 **Course Title:** Advanced Data Structures and Algorithms

L-T-P: 3-0-2 **Credits:** 4 **Subject Area:** PCC

Course Outlines: Recall of basic data structures, algorithms, programs, correctness, efficiency, asymptotic notation, big O, theta, omega, little o, recurrence relations, master theorem, algorithmic upper bounds, lower bounds, adversarial arguments, Divide and Conquer Methods**,** Greedy Techniques, Bellman Ford algorithm, network flows problem, Ford Fulkerson method, maxflow-mincut theorem, longest increasing subsequence, knapsack with and without repetition, independent set in trees, string matching algorithms, naive string matching, NP Completeness and Reductions: Classes P, NP, co-NP. NP-completeness and reducibility, coping with NP-completeness, approximation algorithms. set cover log(n) approximation, 2-approximation for tsp, 2-approximation for vertex cover parameterized algorithms.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Applied Mathematics and Scientific Computing

Subject Code: AMC-509 **Course Title:** Programming Lab

L-T-P: 0-0-6 **Credits:** 3 **Subject Area:** PCC

Course Outlines: Basic programming with Python: Introduction to Jupyter notebook conditional statements and loops, functions, lists, dictionaries, tuples and sets, Numpy library, special matrices and matrix operations in Numpy, system of equations, slicing and indexing, broadcasting, Scipy and its sub packages, linear algebra, optimization, Fourier transformation, integration and ODE, basic statistics, basic image analysis with Scipy, Representation of data through Pandas, Introduction to the concept of visualization.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Applied Mathematics and Scientific Computing

Subject Code: AML- 501 **Course Title:** Approximation Theory

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** PEC

Course outlines: Introduction to approximations theory, best approximations in Normed Spaces, Weierstras Theorem, Bernstein's polynomials, Korovkin theorem, spline approximation of smooth functions in 1D, polynomial and trigonometric approximation of analytic functions in 1D, linear best approximation, best n-term approximation, least square approximations. Properties of the Chebyshev Polynomials. Bernstein's inequality, Jackson's theorems. Approximation by means of Fourier series. Positive linear operators, Monotone operators, Simultaneous approximation, L^p-approximation, Approximation of analytic functions.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Applied Mathematics and Scientific Computing

Subject Code: AML-502 **Course Title:** Advanced Transform Techniques

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** PEC

Course Outlines: Integral Transform – Introduction, Basic concepts and definitions. Review of Fourier Transforms, Hankel Transform– Definition and basic properties, Hankel Transform of derivatives, Applications of Hankel transform to PDEs. Mellin Transform – Definition and properties, Shifting and scaling properties, Mellin transforms of derivatives and integrals, Applications of Mellin transform. Stieltjes Transform – Definition and basic properties of Stieltjes transform, Inversion theorems for Stieltjes transforms, Applications of Stieltjes transforms. Legendre Transform – Definition and basic properties of Legendre transform, Applications of Legendre transforms to Boundary Value Problem. Wavelet transform, wavelet series, basic wavelets (Haar/Shannon/Daubechies), integral wavelet, orthogonal wavelets.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Applied Mathematics and Scientific Computing

Subject Code: AML-503 **Course Title:** Applied Soft Computing

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** PEC

Course Outlines: Overview of soft computing and historical development, Artificial Neural Networks, its philosophy and its similarity to human brain, concept of a neuron, single layer perceptron, Introduction to Fuzzy set theory, Fuzzy set versus crisp set, Crisp relation & fuzzy relations, basic concepts and working principles of Genetic Algorithms, Particle Swarm Optimization and Differential Evolution.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Applied Mathematics and Scientific Computing

Subject Code: AML-504 **Course Title**: Applied Operations Research

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** PEC

Course Outlines: Introduction to network analysis, shortest path problem, construction of minimal spanning tree, flows in networks, job and events, resource allocation and least cost planning, Program Evaluation Review Technique (PERT), PERT COST system. Goal programming model formulation, Game theory: Max-min and Min-max principle, two – person zero-sum games, sequencing analysis: two machine and n jobs (no passing) problem and three machine and n jobs (no passing) problems: different routing, 2 jobs and m machines, n jobs and m machines, branch and bound algorithms, Dynamic Programming, Inventory Models.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Applied Mathematics and Scientific Computing

Subject Code: AML-505 **Course Title:** Mathematical Finance

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** PEC

Course Outlines: Introduction to financial markets, 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. 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, Ito integral. Black-Scholes-Merton (BSM) model, fundamental theorems of asset pricing.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Applied Mathematics and Scientific Computing

Subject Code: AML-506 **Course Title:** Mathematical and Computational Biology

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** PEC

Course Outlines: Single species population growth models, interaction between populations, stability analysis, phase plane analysis, bifurcation analysis, basic models of epidemiology, basic reproduction number, Monte Carlo Simulations, reaction diffusion, stochastic simulation.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Applied Mathematics and Scientific Computing

Subject Code: AML-507 **Course Title:** Computational Differential Equations

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** PEC

Course outlines: Stability Concepts for ODEs, Numerical Solution of IVPs, Higher-order Methods for the IVP, Linear Multistep Methods, Accuracy, Stability, finite difference methods for BVPs, linear and nonlinear two-point BVPs, The Shooting Method, Ansatz Methods for BVPs. Classical PDE Problems, The Finite Difference Method, The Method of Lines for Parabolic PDEs, The Convection-Diffusion-Reaction PDE, The General Nonlinear Parabolic PDE, The Finite Difference Method, Discretization of a Problem with Different BCs, Numerical Stability for Hyperbolic PDEs.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Applied Mathematics and Scientific Computing

Subject Code: AML-508 **Course Title:** Advanced Decision Making

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** PEC

Course Outlines: Historical development and review of decision-making processes, Multi–Criteria Decision Making (MCDM) overview, Pareto optimality, elementary decision analysis, decision trees and influence diagram, Multi–Attribute Decision Making (MADM), Multi–Objective Decision Making (MODM), non-interactive and interactive methods, hybrid MCDM methods.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Applied Mathematics and Scientific Computing

Subject Code: AML-509 **Course Title:** Integral Equations

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** PEC

Course outlines: Classification of integral equations, Fredholm's Integral Equations with symmetric kernel, Eigenfunction expansion, Hilbert-Schmidt theorem, Rayleigh-Ritz method for finding eigenvalue, Singular Integral Equations. Numerical Methods for solving Integral equations. Solution of Volterra integral equation using successive approximation method, Adomian decomposition method, series solution, successive substitution method, resolvent kernel.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Applied Mathematics and Scientific Computing

Subject Code: AML-510 **Course Title:** Advanced Evolutionary Algorithms

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** PEC

Course Outlines: Evolutionary algorithms (EA), their philosophy, significance and historical development, important concepts. Genetic algorithms (GA), early developments, encoding, fitness function, population size, selection, crossover and mutation operators along with the methodologies of applying these operators. binary and real coded GA, Differential Evolution (DE), Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), EA for constrained optimization, Performance enhancement methods in EA: Initial population generation, hybridization models, adaptive models.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Applied Mathematics and Scientific Computing

Subject Code: AML-511 **Course Title:** Logistics and Supply Chain Management

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** PEC

Course Outlines: Introduction to Logistics and Supply Chain Management: Value chain, managing predictable variability, warehousing, inbound and outbound processes, Modes of transportation, transportation infrastructure, freight management, cold supply chain, transportation networks, route planning. Demand Forecasting: Introduction to forecasting, The role of forecasting in a supply chain, Components of a forecast & Forecasting methods. Information Technology (IT) in Supply Chain management (SCM) & Enterprise Resource Planning (ERP).

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Applied Mathematics and Scientific Computing

Subject Code: AML-512 **Course Title:** Advanced Computational Fluid Dynamics

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** PEC

Course Outlines: Basic Concepts of Fluid flow, Finite Volume Method: Discretization methods, Incompressible Navier-Stokes (N-S) equation, Semi–implicit methods, Turbulence Modelling: Introduction to turbulence, Turbulence properties and scales, Reynolds Averaged Navier Stokes (RANS) equation, RANS time averaging, Closure problem, Eddy viscosity model, Introduction to large eddy simulation (LES) and direct numerical simulation (DNS). Compressible Flow: Solution of Euler equations, Explicit and implicit treatment such as Lax-Wendroff, MacCormark, Solution of N-S equation: MacCormack, Jameson algorithm in finite volume formulation, Introduction to Multiphase Flow Modelling, Cavitation modelling.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Applied Mathematics and Scientific Computing

Subject Code: AML-513 **Course Title:** Game Theory & Industrial Organization

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** PEC

Course Outlines: Introduction, strategic games, Nash equilibrium, best response functions, dominated actions, Cournot, Bertrand, Electoral competition, equilibrium for pairwise interactions in a single population, auctions, mixed strategy equilibrium, extensive games with perfect information, bargaining, repeated Prisoner's dilemma.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Applied Mathematics and Scientific Computing

Subject Code: AML-514 **Course Title:** Explainable Artificial Intelligence

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** PEC

Course Outlines: Introduction to explainable AI (XAI), its importance and related terminologies. Broad taxonomy of XAI methods including Intrinsic vs post hoc, model specific vs model agnostic, and local vs global, Trade-off between accuracy and explainability, human friendly explanations, Intrinsically explainable models including Linear Regression, Logistic Regression, Generalized Linear Model (GLM), and Decision Tree, XAI methods including, Partial Dependence Plot (PDP), Conformal Prediction, Individual Conditional Expectation (ICE), Feature Importance, Saliency Maps, Local Interpretable Model-Agnostic Explanations (LIME), Shapley Additive Explanations (SHAP) model, Integrated Gradient (IG).

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Applied Mathematics and Scientific Computing

Subject Code: AML-515 **Course Title:** Stochastic Differential Equations

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** PEC

Course Outlines: General probability spaces, conditional expectation, Brownian motion, Ito's formula, and its applications. Stochastic Differential Equations (SDEs), existence and uniqueness of solutions, Equations with affine coefficients and applications in Finance and Physics. The Black and Scholes model and the theory of option pricing, Modelling interest rates and bonds, Transformation methods to handle SDEs with general coefficients.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Applied Mathematics and Scientific Computing

Subject Code: AMS-501 **Course Title:** Ethics in Artificial Intelligence and Data Science

L-T-P: 2-0-0 **Credits:** 2 **Subject Area:** SSC

Course Outlines: Philosophical frameworks for ethics-foundations of ethics, early theories and philosophers, concepts of ethics in artificial intelligence and data science, strategies & challenges of putting ethics & responsibility into practice, EU's General Data Protection Rules (GDPR), Personal Data Protection Bill, 2019 (PDP Bill), copyright, IPR, ethical issues on data privacy in context with India, data analysis: Types of data, methods for data collection, descriptive and inferential statistics, statistical bias, concept of biased & fair algorithms, types of algorithmic bias, measuring bias in artificial intelligence and machine learning, methods for mitigation of bias, algorithmic accountability.