Indian Institute of Technology Kanpur
Proposal for a New Course

1. Course No: CHE 6XX
2. Course Title: Mathematics for Machine Learning
3. Per Week Lectures: 3 (L), Tutorial: 0 (T), Laboratory: 0 (P), Additional Hours[0-2]: 0 (A), Credits (3-0-0-0) Duration of Course: Full semester
4. Proposing Department: Department of Chemical Engineering

   Other Departments/IDPs which may be interested in the proposed course: ME, AE, MSE

   Other faculty members interested in teaching the proposed course: Sanjeev Garg, H. H. Katkar, Salman Khan
5. Proposing Instructor(s): Indranil Saha Dalal
6. Course Description:
   A) Objectives: The aim of this course is to introduce students to mathematical methods required for Machine learning applications. This is primarily intended for PG students and can serve as a preparation course towards a Machine learning/Deep learning elective. Most topics would be supplemented by computer-based exercises as well. This can also serve as an introductory Machine learning course.

   B) Contents (preferably in the form of 5 to 10 broad titles):
   Lecture-wise break-up (considering the duration of each lecture is 50 minutes)

S. No.	Broad Title	Topics	No. of Lectures
1.	Linear algebra	Systems of linear equations, vector spaces, linear independence, basis, rank, norms, orthogonality	3
2.	Matrix decompositions	Determinant, trace, Eigenvalues and Eigenvectors and their determination, Cholesky decomposition, singular value decomposition	5
3.	Vector calculus	Partial differentiation, gradients, useful identities, backpropagation and automatic differentiation, higher order derivatives, linearization	4
4.	Probability and distributions	Discrete and continuous probability, sum rule, product rule, Bayes' theorem, Gaussian distribution, exponential family, change of variables/inverse transform	6
5.	Introduction to Optimization	Gradient descent, constrained optimization, convex optimization	3
6.	Models and data	Data, models, learning, parameter estimation, probabilistic modelling and inference	2
7.	Linear regression	Problem formulation, parameter estimation, Bayesian linear regression, maximum likelihood	4

8.	Dimensionality reduction with Principal component analysis	Maximum variance perspective, projection perspective, eigenvector computations, low-rank approximation, PCA in high dimensions	4
9.	Density estimation with Gaussian mixture models	Gaussian mixture model, parameter learning via maximum likelihood, EM algorithm	4
10.	Classification with support vector machines	Separating hyperplanes, support vector machine, kernel	5

C) Recommended pre-requisites, if any: None

D) Short summary for including in the Courses of Study Booklet:
Linear algebra, matrix decomposition, probability, optimization, regression, principal component analysis, Gaussian mixture models, Support vector machines

7. Recommended text/reference books:
    1. Marc Peter Deisenroth, A. Aldo Faisal, and Cheng Soon Ong, Mathematics for Machine Learning, Cambridge University Press (2020).
    2. Gilbert Strang, Linear Algebra and Learning from Data, Wellesley-Cambridge Press (2019).

8. Any other remarks: Home assignments and quiz/exams may also consist of computer-based exercises (preferably with Python/Matlab).

Dated: 12/7/2024 Proposer: Indranil Saha Dalal

Dated: DPGC Convener:

The course is approved / not approved

Chairman, SUGC

Dated: 27/09/2022