Mathematics for Machine Learning			
Course Code	**1BMATEC401**	Scheme	2025
Type of Course	Applied Science Course (ASC)	Semester	IV
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	90(42:0:0:48)	SEE Marks	50
Credits	**3**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	3

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

CO1: Apply the concepts of vector spaces, linear transformations, basis, dimension, rank, and nullity to solve problems arising in machine learning and data analysis.

CO2: Analyze inner product spaces, orthogonality, orthonormal bases, Gram-Schmidt orthogonalization, and QR decomposition for efficient representation of data.

CO3: Evaluate eigenvalues, eigenvectors, matrix decompositions, positive definite matrices, singular value decomposition, and matrix differentiation techniques used in machine learning algorithms.

CO4: Apply probability distributions, expectation, variance, covariance, and correlation concepts to model uncertainty and analyze data-driven systems.

CO5: Utilize sampling theory, hypothesis testing, confidence intervals, stochastic processes, and Markov chains for statistical inference and predictive modeling applications.

Module-1: Vector spaces

Vector spaces: Definition and examples, subspace, linear span, Linearly independent and dependent sets, Basis and dimension.

Linear transformations: Definition and examples, Matrix of a linear transformation. Change of bases, Rank and nullity of a linear operator, Rank Nullity theorem.

Number of Hours:8

Module-2: Inner Product Spaces

Inner Product Spaces: Inner product, orthogonal sets, angles and orthogonality, orthonormal Basis, orthogonal projections; Gram-Schmidt orthonormalization process;
QR- decomposition.

Number of Hours:8

Module-3: Eigen values and Eigenvectors

Eigen values and Eigenvectors -Diagonalization, Positive definite Matrices and test for positive definiteness, Singular Value Decomposition (2×2).
Matrix derivatives: Jacobian matrix, Hessian matrix, Gradient of vector and matrix with respect to vector and matrix, pseudo inverse.

Number of Hours:8

Module-4: Probability Distribution

Review of basic probability theory, Random variables-discrete and continuous Probability distribution function, cumulative distribution function.
Mathematical Expectation: mean and variance.
Binomial, Poisson, Exponential and Normal distribution– Problems.
Joint probability distribution: Joint Probability distribution for two discrete random variables, expectation, covariance and correlation.

Number of Hours:9

Module-5: Sampling Theory & Stochastic process

Sampling Theory: Sampling, Sampling distributions, standard error, test of hypothesis for means and proportions, confidence limits for means, student's t-distribution, Chi-square distribution as a test of goodness of fit.
Stochastic process: Stochastic processes, probability vector, stochastic matrices, fixed probability vector, regular stochastic matrices, Markov chains, higher transition probability-problems.

Number of Hours:9

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. **Marc Peter Deisenroth, A. Aldo Faisal, and Cheng Soon Ong**. "Mathematics for Machine Learning", Published by Cambridge University Press, Copyright 2020
2. **Gilbert Strang**, "Linear Algebra and its Applications", 3rd edition, Thomson Learning Asia,2003.
3. **B.S. Grewal**, *Higher Engineering Mathematics*, 45th Edition, Khanna Publishers.

Reference books / Manuals:

4. **Christopher M. Bishop**, *Pattern Recognition and Machine Learning*, Springer, 2006.
5. **Trevor Hastie, Robert Tibshirani and Jerome Friedman**, *The Elements of Statistical Learning*, 2nd Edition, Springer, 2009.
6. **Sheldon Ross**, *A First Course in Probability*, 10th Edition, Pearson Education, 2019.
7. **Erwin Kreyszig**, *Advanced Engineering Mathematics*, 10th Edition, Wiley India.
8. **Kenneth Hoffman and Ray Kunze**, *Linear Algebra*, 2nd Edition, Pearson.
9. **David C. Lay**, Steven R. Lay and Judi J. McDonald, *Linear Algebra and Its Applications*, 5th Edition, Pearson.
10. **H.K. Dass and Er. Rajnish Verma**, *Higher Engineering Mathematics*, S. Chand Publications.

Web links and Video Lectures (e-Resources):

- https://nptel.ac.in/courses/111107137
- NPTEL Courses on Engineering Mathematics
- MIT Open Course Ware Mathematics
- SWAYAM Online Courses

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. **Flipped Classroom Approach**
   - Students review video lectures and reading materials before class.
   - Classroom sessions focus on problem-solving, discussions, and applications of transform techniques and optimization models.
2. **Problem-Based Learning (PBL)**
   - Real-world engineering problems involving Fourier Transforms, Z-Transforms, and Linear Programming are assigned for collaborative solution development.
3. **ICT-Enabled Teaching**
   - Use of MATLAB, Python, and online simulation tools to visualize transforms, optimization problems, and signal-processing applications.
4. **Collaborative Learning**
   Group assignments and mini-projects on optimization models and transform applications.

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)**shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
1.	Assignment at RBL3 and RBL4 levels based on Team Work (TW) activities.	10
2.	GATE-based Aptitude Test.	15

Rubrics **for Learning Activity–1: Assignment (10 Marks)**

Performance Indicator	**Superior (15)**	**Good (12)**	**Fair (10)**	**Needs Improvement (8)**
Quantitative Aptitude	≥90% correct responses	75–89% correct	60–74% correct	<60% correct
Analytical Thinking	Excellent logical reasoning and interpretation	Good reasoning ability	Moderate reasoning	Weak reasoning
Time Management	Completes all questions within allotted time	Completes most questions	Requires additional time	Unable to complete
Accuracy & Precision	Very high accuracy	Good accuracy	Moderate accuracy	Low accuracy

Rubrics for Learning Activity–2: GATE-Based Aptitude Test (15 Marks)

Performance Indicator	Superior (10)	Good (8)	Fair (6)	Needs Improvement (5)
Understanding of Concepts	Demonstrates excellent conceptual clarity and application	Good understanding with minor errors	Basic understanding	Poor understanding
Problem Solving Ability	Solves all problems correctly with proper methodology	Solves most problems correctly	Partial solutions with errors	Unable to solve problems effectively
Mathematical Accuracy	Calculations and derivations are error-free	Minor computational errors	Several errors	Significant errors
Presentation & Organization	Well-structured, neat, and professionally presented	Organized with minor deficiencies	Average presentation	Poor presentation

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester		
Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1.	Collaborative Problem Solving on Gram-Schmidt Orthogonalization and QR Decomposition	6
2.	Mini Project on Eigenvalues, Eigenvectors and Principal Component Analysis (PCA)	6
3.	Team-Based Analysis of Hypothesis Testing and Confidence Intervals	6
4.	Group Presentation on Applications of SVD in Image Compression and Data Analytics	6
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1.	Python Programming Practice using NumPy for Matrix Operations	6
2.	Study of Machine Learning Applications using SVD and PCA	6
3.	Preparation of Summary Notes on Markov Chains and Stochastic Processes	6
4.	Literature Survey on Mathematical Foundations of Machine Learning	6

Continuous Internal Evaluation (CIE)

1. The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.
2. Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.
3. The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.
4. A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

1. For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
2. For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.
3. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).