IIT Mandi
Proposal for a new course

Course name: *Matrix Theory*
Course number: *EE 522*
Credits: *3 - 0 - 0 - 3*
Prerequisites: *IC111 Linear Algebra, or a similar course or permission from the instructor.*
Intended for: **M.Tech./MS/PhD in School of computing and electrical engineering(SCEE) and School of Engineering (SE).**
The 3rd/4th year undergraduate students.
Distribution: *Core for M.Tech.- CSP. Elective for other postgraduates and III and Final Year B.Tech.*
Semester: *Odd semester (August to December)*

Preamble: Matrix theory has found application in several disciplines of engineering, such as, electrical, mechanical, structural engineering. As various branches of engineering deal with linear systems, which can be expressed using vectors and matrices, knowledge of matrix theory is must for modern engineers. Though due to advances in computation technology large linear systems can solved within reasonable time limit, but some insights from matrix theory, in many cases, can reduce the computational task significantly.

Course Modules with Quantitative lecture hours: The topics to be covered are:

Background and review (6 lecture hours) Quick recapitulation of linear system of equations, and their solutions, Matrices, Determinant, Rank, Linear Vector spaces, Basis, Dimensions, Subspaces, Inner product and orthogonality, Range space and null space, Eigenvalues and eigenvectors.

Norms for vectors and matrices (4 lecture hours) Vector norms and their properties, Matrix norms, Error analysis in linear systems

Canonical forms, Symmetric and Hermitian matrices (5 lecture hours) Jordon Canonical form, Definition, properties, and characterization of Hermitian matrices, Congruence and simultaneous diagonalization of Hermitian and symmetric matrices.

Perturbation theory and Eigenvalue problems (5 lecture hours) The condition of Eigenvalues, Condition numbers and their application, location and perturbation of Eigenvectors, Generalized Eigenvalue problems, Rayleigh Quotient

Matrix factorization and Least square problems (6 lecture hours) Singular value decomposition, generalized pseudoinverses, QR factorization, PCA, Least square problems

Sparse matrices, their analysis and algorithms (4 lecture hours) Graphs and matrices, Linear solvers and their complexity, Sparse Gaussian elimination, Krylov-

subspace iterations, Preconditioned methods: Incomplete factorization, Sparse approximate inverses, Sparse eigenvalue and singular value problems.

Different types and matrices, their properties and analysis (4 lecture hours) Irreducible, primitive, stochastic and doubly stochastic matrices; Properties of positive definite matrices, Sparse matrices and their analysis, Toeplitz and Circulant matrices

Random matrices and their applications (4 lecture hours) Introduction to randomness: concentration of measure, Lemma of Johnson and Lindenstrauss, Random matrices: Matrix norms, Golden-Thompson inequality, Non-commutative Bernstein inequality, Lieb's theorem, Applications: matrix multiplication and matrix completion

Numerical analysis and iterative methods (4 lecture hours) Overview of iterative methods, Arnoldi iterations, Generalized minimal residual method, Lanczos iterations, Conjugate gradients, Biorthogonalization method

Textbooks:

1. *Matrix Analysis*, Roger A. Horn and Charles R. Johnson, Cambridge university press, 2012.
2. *Matrix computations*, Gene H. Golub and Charles F. Van Loan, 3ed Ed., John Hopkins University Press, 2012..

Additional References:

1. *Matrix Theory,* David Lewis, 3rd edition, 2014, Allied Publishers
2. *Direct Methods for Sparse Linear Systems,* T. A. Davis, SIAM, 2006
3. *An Introduction to Matrix Concentration Inequalities*, Joel Tropp, 2015
4. *Topics in Random Matrix Theory,* Terence Tao, AMS, 2012
5. *Numerical linear algebra*, Lloyd N. Trefethen and David Bau III, Siam, 1997.
6. *Matrix analysis for scientists and engineers*, Alan J. Laub, Siam, 2005.
7. *Linear algebra in action*, Harry Dym, American Mathematical Soc., 2013.
8. *Linear Algebra and its application*, Gilbert Strang, 3rd Ed., Harcourth Brace Jovanovich Pubs.