# King Fahd University of Petroleum and Minerals
## Department of Mathematics
## Syllabus Math 557
### Instructor: Dr. Muhammad Yousuf

**Course Title:** Applied Linear Algebra

**Course Description:** Basics concepts from linear algebra and numerical analysis. Direct methods for large, sparse linear systems, Cholesky and LU factorizations. Regularization of ill-conditioned least squares problems. SVD and QR factorizations. Sensitivity and conditioning of linear systems and least square problems. Stationary and non-stationary iterative methods, multigrid methods. Matrix theory including spectral decompositions, and eigenvalue perturbation theory. Eigenvalue and QR algorithm, and computations of SVD. Applications.

**Prerequisite:** Graduate standing

**Textbook:** Numerical Linear Algebra and Matrix Factorization, Lyche, Springer (2020)

**References:**

- Numerical Linear Algebra, L. Trefethen and D. Bau, SIAM (1997)
- Numerical Linear Algebra, W. Lyton and M. Sussman, World Scientific (2020)
- Linear Algebra and Matrix Computations with MATLAB, D. Xue, De Gruyter (2020)
- Numerical Analysis: Mathematics of Scientific Computing by Kincaid and Cheney, Brooks/Cole Publishing, (2002)

**Learning Outcomes:** Upon completion of this course, students will be able to:

1. Apply fundamental numerical linear algebraic concepts.
2. Estimate stability of solutions to linear algebraic equations & eigenvalue problems.
3. Utilize factorizations for efficiently solving linear systems and least squares problems.
4. Use the underlying principles of iterative algorithms for computing and selecting.
5. eigenvalues and finding singular values.
6. Estimate the speed of convergence and computational complexity of the selected numerical algorithms.

**Course Main Objectives**

1. Introduce various iterative and factorization techniques for solving large sparse linear systems of equations.
2. Discuss dense linear systems.
3. Study computation of eigenvalues, least squares problems, and error analysis.

**Assessment:**

Assignments and Projects 30% (15+15)

Two Majors 40% (20+20)

Final Exam 30%.

| WK | Date | Topics | MATLAB Implementation |
|---|---|---|---|
| 1 | Aug 27 – 31 | Notations and review of basic concepts | Basic matrix operations |
| 2 | Sep 03 – 07 | Matrix Arithmetic, Inverse, Determinants | Compute Inverse, determinants |
| 3 | Sep 10 – 14 | Direct Method to solve Linear Systems: Gaussian Elimination and Backward Substitutions | Verify solutions using Matlab |
| 4 | Sep 17 – 21 | Special Matrices: Positive Definite, Diagonally Dominant and Triangular matrices. | |
| 5 | Sep 25 - 28 | LU factorization to solve linear systems | Verify solutions using Matlab |
| 6 | Oct 01 – 05 | LDL and Cholesky Factorization | |
| 7 | Oct 08 – 12 | Eigenvalues, Eigenvectors and Singular Values | Compute using Matlab |
| 8 | Oct 15 – 19 | The Singular Value Decomposition: SVD | |
| 9 | Oct 22 – 26 | Least Squares | |
| 10 | Oct 29 – Nov 2 | Iterative Methods to solve linear systems | Matlab Implementation |
| 11 | Nov 05 – 09 | Conjugate gradient method | |
| 12 | Nov 12 – 16 | Eigenvalues approximation: **Gershgorin's circel theorem** | Matlab Implementation |
| 13 | Nov 26 – 30 | The QR Algorithm: The Power method | Matlab Implementation |
| 14 | Dec 03 – 07 | Project report and presentation | |
| 15 | Dec 10 – 14 | Review | |

National Holiday: Sep 24, 2023

Midterm Break: Nov 19 – 23, 2023

Normal Sunday Class: Dec 17, 2023