King Fahd University of Petroleum and Minerals
Department of Mathematics and Statistics
Semester I, 2016-2017 (161)
(Dr. Faisal A Fairag)

Course #:	Math 595 (Reading and Research I)
Title:	Preconditioning Techniques for Saddle Point Systems
Objectives:	The objective of this course is to introduce the student into the active area of research of preconditioning techniques and solvers for saddle point systems.
Textbook:	[1] Benzi, M., Golub, G. H., & Liesen, J. (2005). Numerical solution of saddle point problems. Acta numerica, 14, 1-137. [2] Trefethen, L. N., & Bau III, D. (1997). Numerical linear algebra (Vol. 50). SIAM.
References:	[3] Saad, Y. (2003). Iterative methods for sparse linear systems. Siam. [4] Murphy, M. F., Golub, G. H., & Wathen, A. J. (2000). A note on preconditioning for indefinite linear systems. SIAM Journal on Scientific Computing, 21(6), 1969-1972. [5] Rui, H., & Pan, H. (2012). A Block-Centered Finite Difference Method for the Darcy--Forchheimer Model. SIAM Journal on Numerical Analysis, 50(5), 2612-2631.
Intended for	Mr. Mohsen Al Shahrani (ID 201030180)
Outcomes:	After taking this unit, student should be able to: 1. Demonstrate understanding of spectral theory and eigenvalues analysis for the preconditioned saddle point system. 2. State and prove basic results in the convergence analysis of Krylov subspace methods. 3. State and prove basic results in the eigenvalues analysis of preconditioned saddle point system. 4. Assemble all cell-centered finite difference matrices. 5. To be able to recognize and implement finite difference approximations. 6. to write Matlab code to implement the algorithms developed in the course 7. To be able to use mathematical packages (MATLAB, AGMG, Templates, IFISS) to solve problems and to visualize the results
Software:	MATLAB , Templates, AGMG, IFISS
Prerequisites	Math-550
Grading:	Weekly presentations, Homework assignments and Projects
maximum % overlap with existing courses	4%

The weakly breakdown of the course is as follows

Week #	Topic
1-2	Introduction: Problem statement and classification, Sparsity, structure and size
	Applications leading to saddle point problems
	A complete Example: Darcy and Darcy–Forchheimer equations, Cell-Centered Finite Difference Method: one dimensional problem Cell-Centered Finite Difference Method: two dimensional problem Assembly of the Finite difference matrices
3-4	Properties of saddle point matrices
	Block factorizations, the Schur complement, Congruent transformation and Sylvester's Law of Inertia
5	Solvability conditions: Symmetric case
	Solvability conditions: General case
6-7	Spectral properties of saddle point matrices
	Conditioning issues
8-9	Overview of solution algorithms
	Schur complement reduction
	Null space methods
	Coupled direct solvers
	The Uzawa methods
10-11	Krylov subspace methods: General theory, Convergence analysis and Implementation details
12-13	Preconditioners: Block preconditioners, Block triangular preconditioners and Approximating the submatrices A and S
14	Constraint and indefinite preconditioning
	Hermitian/skew-Hermitian preconditioning
	Approximate and incomplete factorization methods
15	Newton's Method in several variables