Course Specification

(Postgraduate Programs)

Course Title:	**Spectral Methods**
Course Code:	**MAT 7243**
Program:	**Doctor of Philosophy in Mathematics**
Department:	**Mathematics and Statistics**
College:	**Science**
Institution:	**Imam Mohammad Ibn Saud Islamic University**
Version:	**2024 – V1**
Last Revision Date:	**None**

Table of Contents

A. General information about the course:

1. Course Identification

1. Credit hours:					
4 (4 Lectures, 0 Lab, 0 Tutorial)					
2. Course type					
A.	☐ University	☐ College	☒ Program	☐ Track	☐ Others
B.	☐ Required		☒ Elective		
3. Level/Year at which this course is offered: Level 3/ Year 2					
4. Course general Description:					
This is an introductory course on spectral methods for solving both ordinary and partial differential equations (ODEs, PDEs) and addresses graduate students who are interested in numerical methods. Some basic theoretical results on spectral approximations with practical algorithms for implementing spectral methods are presented. The course specially emphasizes on how to design efficient and accurate spectral algorithms on different geometry for solving PDEs of current interest.					
5. Pre-requirements for this course (if any):					
None.					
6. Co-requisites for this course (if any):					
None.					
7. Course Main Objective(s):					
The objectives of the course are essentially twofold: first, provide and help the students to understand the essential of the advanced mathematical foundations for any classical numerical methods, and, secondly, introduce students to spectral methods and related computer algorithms. The course also allows to show that how spectral methods can be used in different applications and settings for both differential and partial differential equations. The emphasis will be both theoretical aspects, such as error and stability analysis, as well as certain implementation issues. The presented methods will be illustrated using well-known PDEs from mathematical physics.					

2. Teaching mode (mark all that apply)

No	Mode of Instruction	Contact Hours	Percentage
1	Traditional classroom	60	100%
2	E-learning	0	0%
3	Hybrid • Traditional classroom • E-learning	0	0%
4	Distance learning	0	0%

3. Contact Hours (based on the academic semester)

No	Activity	Contact Hours
1.	Lectures	60
2.	Laboratory/Studio	0
3.	Field	0
4.	Tutorial	60
5.	Others (specify)	0
Total		60

B. Course Learning Outcomes (CLOs), Teaching Strategies and Assessment Methods

Code	Course Learning Outcomes	Code of CLOs aligned with program	Teaching Strategies	Assessment Methods
1.0	Knowledge and understanding			
1.1	To list spectral methods for a given problem.	K1, K2	4 lecture hours\week	Direct: Regular Exams
1.2	To write suitable computer program/code to solve a given problem.	K1, K2	• 4 lecture hours\week • Self-study	Direct: Short Quizzes
2.0	Skills			
2.1	To develop techniques of proof in the collocation methods.	S1, S2	Self-study	Direct: • Participations • Short Quizzes
2.2	To develop oral communication and technical writing skills through spectral-Galerkin Methods.	S4	Real-life problems	Direct: Homework and Mini projects
2.3	To use Internet in searching for more spectral-Galerkin Methods.	S3	Real-life problems	Direct: Short Quizzes
2.4	To demonstrate deep proofs in using different spectral methods.	S1, S2	Self-study	Direct: Participations
3.0	Values, autonomy, and responsibility			
3.1	To work individually.	V1, V2	Personal questions	Direct: Participation
3.2	To work in groups.	V1, V3	Teamwork and class discussions.	Direct: Homework and Mini projects

C. Course Content

No	List of Topics	Contact Hours
1.	**Spectral-Collocation Methods:** Differentiation Matrices for Fourier Collocation Methods, Differentiation Matrices for Polynomial Basis Functions, Fourier Collocation Method for PDEs, Review on Time Discretization Methods. Chebyshev Collocation Methods, Legendre Collocation Method, Collocation Methods in Weak Form.	18
2.	**Spectral-Galerkin Methods:** Introduction and General Set Up, Fourier Spectral and Pseudo-pectral Method, Legendre-Galerkin Method, Chebyshev-Galerkin Method, Iterative Methods and Pre-Conditioning, Spectral-Galerkin for Higher Order Equations, Error Estimates	12
3.	**Spectral Methods in Unbounded Domains:** Hermite Spectral Methods, Laguerre Spectral Methods, Spectral Methods with Rational Functions	8
4.	**Spectral Methods in Multi-Dimensional Domains (optional iftime allow):** Spectral-Collocation in Rectangular Domains, Spectral-Galerkin in Rectangular Domains, Fast Poisson Solver	8
5.	**Applications:** Spectral Methods for Wave Equation, Spectral Approximation of Stokes Equations Spectral Approximation of Navier-Stokes Equations	14
Total		60

D. Students Assessment Activities

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
1.	HomeWorks, Quizzes, Mini projects	During the semester	30%
2.	Midterm	Week 9-10	30%
3.	Final Exam	Week 15-16	40%

*Assessment Activities (i.e., Written test, oral test, oral presentation, group project, essay, etc.).

E. Learning Resources and Facilities

1. References and Learning Resources

Essential References	**Jie Shen and Tao Tang**, Spectral and High-Order Methods with Applications; Science Press, China, 2006.
Supportive References	• Lloyd N. Trefethen, *Spectral Methods in Matlab*, SIAM, USA, 2000 • C Canuto et al., *Spectral Methods, Fundamentals in Single Domains*, Springer-Verlag, Berlin, 2006 (Can be found as electronic resource at NUS central library.)

	• C Canuto et al., *Spectral Methods, Evolution to Complex Geometries and Applications to Fluid Dynamics*, Springer-Verlag, Berlin, 2007.
Electronic Materials	**None**
Other Learning Materials	**None**

2. Educational and Research Facilities and Equipment Required:

Items	Resources
facilities (Classrooms, laboratories, exhibition rooms, simulation rooms, etc.)	▪ **Each class room should be equipped with a whiteboard and a projector.** ▪ **Laboratories should be equipped with computers and an internet connection.**
Technology equipment (projector, smart board, software)	**The rooms should be equipped with data show and Smart Board.**
Other equipment (depending on the nature of the specialty)	**None**

F. Assessment of Course Quality

Assessment Areas/Issues	Assessor	Assessment Methods
Effectiveness of teaching	**Students**	**During the semester and at the end of the course each student will complete two evaluation forms.**
Effectiveness of Students assessment	**Instructor**	**At the end of each semester the course instructor should complete the course report, including a summary of student questionnaire responses appraising progress and identifying changes that need to be made if necessary.**
Quality of learning resources	**Students**	**During the semester and at the end of the course each student will complete two evaluation forms.**
The extent to which CLOs have been achieved	**Instructor**	**At the end of each semester the course instructor should complete the course report, including a summary of student questionnaire responses appraising progress and identifying changes that need to be made if necessary.**
Other	**None**	

Assessors (Students, Faculty, Program Leaders, Peer Reviewer, Others (specify)

Assessment Methods (Direct, Indirect)

G. Specification Approval

COUNCIL /COMMITTEE	MATHEMATICS AND STATISTICS DEPARTMENT COUNCIL
REFERENCE NO.	8/1446
DATE	05/04/1446 (08/10/2024)