Course Specification
(Bachelor)

Course Title:	**Introduction to Numerical Optimization**
Course Code:	**MAT 1444**
Program:	**Bachelor of Science in Applied Mathematics**
Department:	**Mathematics and Statistics**
College:	**Science**
Institution:	**Imam Mohammad Ibn Saud Islamic University**
Version:	**2024 – V1**
Last Revision Date:	**08/10/2024**

Table of Contents

A. General information about the course:

1. Course Identification

1. Credit hours:					
3 (2 Lectures, 0 Lab, 2 Tutorial)					
2. Course type					
A.	☐University	☐ College	☒ Department	☐Track	☐Others
B.	☒ Required		☒ Elective		
3. Level/year at which this course is offered:					
Level 6 / Year 3 or Level 7 / Year 4					
4. Course general Description:					
• To provide students a good understanding on constrained and unconstrained optimization whose content is described in detail in this syllabus. • To perform some algorithms and codes in order to deepen programming and numerical analysis tools used in this course. MATLAB software will be handled. • To allow students understanding of the above concepts through study cases and occasional computer-based homework problems.					
5. Pre-requirements for this course (if any):					
MAT 1253, MAT1341					
6. Co-requisites for this course (if any):					
None.					
7. Course Main Objective(s):					
• Maximizing or minimizing a certain quantity, that is, an objective function that models a system and satisfies a required set of specifications, called constraints, is a frequent problem in science, engineering, business and economics. The function allows comparison of the different choices for determining which might be "best". For instance, by finding an alternative with the most cost effective or highest achievable performance under the given constraints, by maximizing desired factors and minimizing undesired ones. • Numerical Optimization turns out to be considerably important for solving such problems. This course aims at training students for acquiring a basic mathematical understanding of modern approaches to numerical optimization and discussing practical aspects of implementation for solving optimization problems. The students learn how to find analytical solutions to some optimization problems.					

2. Teaching mode (mark all that apply)

No	Mode of Instruction	Contact Hours	Percentage
1	Traditional classroom	60	100%
2	E-learning	0	0%

No	Mode of Instruction	Contact Hours	Percentage
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**	30
2.	**Laboratory/Studio**	
3.	**Field**	0
4.	**Tutorial**	30
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 outline the principles of optimization.**	**K1, K2**	**●3 lecture hours\week**	**●Regular Exams**
1.2	**To memorize various types of algorithms for solving optimization problems.**	**K1, K2**	**●2 tutorial hours\week ●Self-study**	**●Assignments ●Short Quizzes**
2.0	**Skills**			
2.1	**To develop techniques of advanced optimization methods.**	**S1, S2**	**Real-life problems**	**Short Quizzes**
2.2	**To present various numerical algorithms of optimization clearly**	**S4**	**Self-study**	**Participations**

Code	Course Learning Outcomes	Code of CLOs aligned with program	Teaching Strategies	Assessment Methods
	and precisely both orally and in writing.			
2.3	**To use Internet in searching for new improvements of usual numerical algorithms of optimization.**	**S5**	**Real-life problems**	**Short Quizzes**
2.4	**To compute orders and complexities of usual numerical optimization algorithms and their variants.**	**S3**	**Self-study**	**Participations**
3.0	**Values, autonomy, and responsibility**			
3.1	**Engage in group discussions and critical interactions**	**V1, V3**	**Personal questions**	**Participation**
3.2	**differentiate betwee n valid and fallacious Mathematical arguments to model real problem involving differential equations.**	**V1, V2**	**Team work**	**Homework and Mini-projects**

C. Course Content

No	List of Topics	Contact Hours
1.	**Introduction:** Examples of optimization problem occurring in science, engineering and economics.	**6**
2.	**Univariate optimization:** Local and global minima, Necessary and sufficient conditions of the first and second order, Iterative numerical methods for univariate optimization: Exhaustive grid search, Golden section search, Brent's method, Newton's method, Secant method.	**14**
3.	**Unconstrained multivariate optimization:** Necessary and sufficient conditions of the first and second order, The case of convex functions, Numerical algorithms for nonlinear multivariate optimization: Linear and	**15**

	superliner convergence, Steepest descent algorithm, Quasi-Newton's methods, Broyden-Fletcher-Goldfarb-Shanno (BFGS) algorithm, Conjugate gradient Methods.	
4.	**Constrained multivariate optimization:** Examples, Equality constraints. Lawrentians and optimality conditions. Geometric interpretation, Equality and inequality constraints, The case of convex programs, Algorithms for constrained optimization: Primal methods: feasible directions methods, active set methods, gradient projection; Penalty and barrier methods.	**15**
5.	**Introduction to evolutionary Algorithms:** Principles, Selection, Recombination, Mutation and Reinsertion, Examples and applications.	**10**
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 term	10%
2.	First Midterm	Week 5-6	25%
3.	Second Midterm	Week 10-11	25%
4.	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	**Numerical Optimization, Jorge Nocedal, Stephen J. Wright, edition 2, Springer 2006 (Main Reference).**
Supportive References	***-An introduction to algorithms for non-linear optimization*; N. Gould, S. Leyffer; Springer, 2003.** ***-Numerical Optimization with Applications*; 1st Edition, S. Chandra, Jayadeva, Aparna Mehra; Alpha Science Intl. Ltd., 2009.** ***-Genetic algorithms on search, optimization and machine learning; D. Goldberg; Addison-Wesley Professional, 1989.***
Electronic Materials	
Other Learning Materials	

2. Required Facilities and equipment

Items	Resources
facilities (Classrooms, laboratories, exhibition rooms, simulation rooms, etc.)	• **Classrooms:** Equipped with whiteboards, projectors, and Smart Boards for interactive lessons and group discussions. • **Laboratories:** Feature computers with internet access, enabling hands-on activities and exploration of algebraic and trigonometric concepts. • **Exhibition Rooms:** Spaces for showcasing projects and presentations to encourage collaborative learning.
Technology equipment (projector, smart board, software)	• **Data Show Projectors:** For clear presentations in classrooms and labs. • **Smart Boards:** To enhance interactivity during lessons. • **Mathematical Software:** Essential for graphing and analysis.
Other equipment (depending on the nature of the specialty)	• **Computers:** For mini-project and homework and practical applications in laboratories. • **Advanced Calculators:** For computations and problem-solving and supporting the study of limits, continuity, and differentiation. • **Whiteboards and Markers:** To facilitate brainstorming and collaboration.

F. Assessment of Course Quality

Assessment Areas/Issues	Assessor	Assessment Methods
Effectiveness of teaching	Faculty, Program Manager, Students, Course Coordinator	- **Student Course Evaluation**: Student feedback surveys to assess teaching quality (clarity, engagement, delivery). - **Instructor Course Report**: Instructor reflection on their teaching effectiveness and challenges. - **Classroom Observations**: Conducted by the program manager or course coordinator to directly observe teaching methods. - **Benchmarking Between Male and Female Sections**: Compare student evaluations and performance across gender-based sections to identify any disparities in teaching effectiveness. - **Advisory Board Feedback**: Gathering insights on teaching methods from external academic or industry professionals.
Effectiveness of Students assessment	Faculty, External Reviewers, Program Manager, Course Coordinator	- **Alignment of Assessments with CLOs**: Ensuring exams, assignments, and projects measure the intended CLOs. - **Benchmarking Between Semesters**: Comparing assessment effectiveness across different semesters to maintain consistency and improvement. - **CLOs Assessment Excel Sheet**: Tracking student performance in relation to CLOs to evaluate the strength of assessments. - **Instructor Course Report**: Faculty analysis of assessment outcomes and potential adjustments. - **External Audit/Reviewers**: External examiners review assessments for rigor and fairness.

Assessment Areas/Issues	Assessor	Assessment Methods
Quality of learning resources	Program Manager, Librarians, Faculty, Course Coordinator	- **Student Course Evaluation**: Students provide feedback on the usefulness and availability of learning resources (textbooks, software, etc.). - **Instructor Course Report**: Faculty report on the adequacy and relevance of learning materials. - **Resource Usage Statistics**: Data on the usage of learning resources (digital/physical) such as library access, software downloads. - **Benchmarking Between Sections/Semesters**: Compare resource satisfaction across male/female sections and over semesters. - **Advisory Board Input**: External experts suggest updated or alternative resources to align with industry or academic developments.
The extent to which CLOs have been achieved	Faculty, Program Manager, External Reviewers, Course Coordinator	- **CLOs Assessment Excel Sheet**: Regular tracking of student performance for each CLO based on exams, projects, and assignments. - **Instructor Course Report**: Faculty reflection on CLO achievement and any gaps identified. - **Student Course Evaluation**: Students assess whether they feel they've met the course learning outcomes. - **Benchmarking Between Semesters**: Analyze CLO achievement across different semesters to ensure continuous improvement. - **Advisory Board Feedback**: Assess whether CLOs are aligned with industry or academic standards and if students are adequately prepared.
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)**