# Course Specification

(Postgraduate Programs )

| | |
|---|---|
| Course Title: | **Numerical Optimization** |
| Course Code: | **MAT 7245** |
| 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 course describes an important part of mathematics used to solve minimization problems. In this course fundamentals in optimization are developed and Matlab programming is handled. Theoretical and numerical aspects will be both considered. | | | | | |
| **5. Pre-requirements for this course** (if any)**:** | | | | | |
| None. | | | | | |
| **6. Co-requisites for this course** (if any)**:** | | | | | |
| None. | | | | | |
| **7. Course Main Objective(s):** | | | | | |
| The objective of this course is to provide a good understanding on constrained and unconstrained optimization in one and several dimension spaces. For nonlinear problems. Convex problems will also be considered. In addition, the course helps to perform some algorithms and codes in order to deepen programming and numerical analysis. MATLAB software will be handled. | | | | | |

### 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<br>• Traditional classroom<br>• 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** | 0 |
| 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 recognize mathematical modeling and operations research techniques | K1, K2 | 4 lecture hours\week | Direct: Regular Exams |
| 1.2 | To record complex problems that require making decisions in situations of complex and uncertain nature.. | K1, K2 | • 4 lecture hours\week<br>• Self-study | Direct: Short Quizzes |
| **2.0** | **Skills** | | | |
| 2.1 | To develop techniques of proof in univariate optimization. | S1, S2 | Self-study | Direct:<br>• Participations<br>• Short Quizzes |
| 2.2 | To develop oral communication and technical writing skills through techniques in constrained and Unconstrained multivariate Optimization | S3 | Real-life problems | Direct: Homework and Mini projects |
| 2.3 | To use Internet in searching for Gradient methods. | S4 | Real-life problems | Direct: Short Quizzes |
| 2.4 | To carry out deep proofs in linear and nonlinear optimization. | S1, S2 | Self-study | Direct: Participations |
| **3.0** | **Values, autonomy, and responsibility** | | | |
| 3.1 | Work with independence and responsibility. | V1, V2 | Personal questions | Direct: Participation |
| 3.2 | Lead team works. | V1, V3 | Teamwork and class discussions. | Direct: Homework and Mini projects |

## C. Course Content

| No | List of Topics | Contact Hours |
|---|---|---|
| 1. | Univariate Optimization: Introduction (local and global minima, Necessary condition, etc.), Dichotomous search, Fibonacci search, | 17 |

| | | |
|---|---|---|
| | Golden section search, Newton's and secant methods, remarks on line search methods. Quadratic and cubic interpolations, Algorithm of Davies, Swann and Campey, Inexact line Searches | |
| 2. | Unconstrained multivariate Optimization: Gradient methods: Steepest-Descent Method, Newton Method, Gauss-Newton Method, Conjugate-direction methods: Conjugate Directions, Basic Conjugate-Directions Method, Conjugate-Gradient Method, Minimization of Nonquadratic Functions, Fletcher-Reeves Method, Powell's Method, Partan Method. Minimax methods: Problem Formulation, Minimax Algorithms, Improved Minimax Algorithms. Quasi- Newton methods Rank-One Method, Davidon-Fletcher-Powell Method, The Broyden Family | 20 |
| 3. | Constrained multivariate Optimization: Fundamentals of constrained optimization: Lagrange Multipliers, First-Order Necessary Conditions, Second-Order Conditions, Convexity, Duality, Quadratic and convex programming: Convex QP Problems with Constrained multivariate Optimization: Fundamentals of constrained optimization: Lagrange Multipliers, First-Order Necessary Conditions, Second-Order Conditions, Convexity, Duality, Quadratic and convex programming: Convex QP Problems with Equality Constraints, Interior-Point Methods for Convex QP Problems, Cutting-Plane Methods for CP Problems, Semidefinite and second-order cone programming: Primal and Dual SDP Problems, Primal-Dual Path-Following Method, Predictor-Corrector Method, Projective Method of Nemirovski and Gahinet, Second-Order Cone Programming. General nonlinear optimization problems: Sequential Quadratic Programming Methods, Modified SQP Algorithms, Interior-Point Methods | 23 |
| 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** | • Andreas Antoniou, Wu-Sheng Lu, PRACTICAL OPTIMIZATION Algorithms and Engineering Application, Springer, 2007<br>• J. Nocedal and S. J. Wright, Numerical Optimization; Springer, 2nd Ed. 2006. |
| **Supportive References** | • N. Gould and S. Leyffer, An Introduction to Algorithms for Nonlinear Optimization; Springer 2003.<br>• S. Chandra, Jayadev and Aparna Mehra, Numerical Optimization with Applications, Alpha Science Intl Ltd; 1st Ed., 2009. |
| **Electronic Materials** | None |
| **Other Learning Materials** | None |

## 2. Educational and Research Facilities and Equipment Required:

| Items | Resources |
|---|---|
| **facilities**<br>(Classrooms, laboratories, exhibition rooms, simulation rooms, etc.) | ▪ Each class room should be equipped with a whiteboard and a projector.<br>▪ Laboratories should be equipped with computers and an internet connection. |
| **Technology equipment**<br>(projector, smart board, software) | The rooms should be equipped with data show and Smart Board. |
| **Other equipment**<br>(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 |

| Assessment Areas/Issues | Assessor | Assessment Methods |
|---|---|---|
| | | 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

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