4/1/4. Course Specification:

COURSE SPECIFICATIONS
Form

Course Title: **Numerical Analysis (2)**

Course Code: **4046707-4**

Course Specifications

Institution: Umm Al-Qura University Date : 31/10/2018
College/Department: Faculty of Applied Science/ Department of Mathematical Sciences

A. Course Identification and General Information

1. Course title and code: Numerical Analysis (2) (4046707-4)
2. Credit hours: 4hrs
3. Program(s) in which the course is offered. (If general elective available in many programs indicate this rather than list programs) Master in Mathematics
4. Name of faculty member responsible for the course: Dr. Hala Ahmad Hejazi
5. Level/year at which this course is offered: Level 3/ Master
6. Pre-requisites for this course (if any) Numerical Solutions of Differential Equations (1) (4045703-4)
7. Co-requisites for this course (if any) --
8. Location if not on main campus -- Al-Abidiyah campus and Al-Zahir campus
9. Mode of Instruction (mark all that apply)

Mode	Mark		Percentage
a. traditional classroom	√	What percentage?	85
b. blended (traditional and online)		What percentage?	
c. e-learning	√	What percentage?	15
d. correspondence		What percentage?	
f. other		What percentage?	

Comments:

B Objectives

1. What is the main purpose for this course? The main purpose of this course is to provide students with more advanced numerical methods, numerical techniques and programming skills that will allow them to solve more complex real world problems that involve differential equations. They will become familiar with the methodologies for developing numerical algorithms that can be employed for problems that would otherwise be unsolvable.
2. Briefly describe any plans for developing and improving the course that are being implemented. (e.g. increased use of IT or web based reference material, changes in content as a result of new research in the field) Search for more online references materials.

C. Course Description (Note: General description in the form used in Bulletin or handbook)

Course Description: Many real world problems are not solvable analytically, meaning that it is necessary to develop numerical methods to solve these problems. Additionally, applying these methods to large problems requires the algorithms to be implemented in a computer language such as MATLAB. This course addresses both the theoretical development of numerical methods and their implementation in MATLAB

1. Topics to be Covered		
List of Topics	No. of Weeks	Contact hours

Taylor and Runge-Kutta Methods • Introduce Euler's algorithm for the solution of systems of ordinary differential equations and the θ method. • Develop error bounds for the growth of the error in the θ method for equations $\dot{y} = f(t, y)$ when f satisfies a Lipshitz condition. • Introduce Taylor's method for the numerical solution of ODE's and the order of a numerical algorithm. • Describe Heun's method and use it to introduce a 2-stage Runge-Kutta algorithm. • Establish the classical 3-stage and 4-stage Runge-Kutta algorithms RK3 and RK4. • Introduce several Runge-Kutta 45 schemes and explain how these may be used to adaptively modify the integration step-size to meet a prescribed error tolerance. Possible schemes are Runge-Kutta Fehlberg, Runge-Kutta Cash-Karp, Runge-Kutta Mersen and Runge-Kutta Butcher.	3	12

Linear Multi-Step Methods • Illustrate the idea of a linear multi-step method using Simpson's rule to integrate the equation $\acute{y} = f(t, y)$ over the interval $[x_k - h, x_k + h]$. Briefly discuss the advantages and disadvantages of this approach by comparison with RK4. • Introduce the form of the general linear multi-step method. Describe well known examples such as the Implicit Euler scheme, Trapezoidal scheme and a low order Adams-Bashforth method. • Demonstrate how the finite difference operator can be used to construct linear multi-step algorithms using backward differentiation. • Introduce the concept of zero stability and establish the classical stability result for the location of the zeros of the associated characteristic polynomial, namely that the zeros all lie within the unit disc. • Briefly describe the distinction between an Adams-Bashforth method (explicit) and an Adams-Moulton method (implicit). Summarize, consistency, convergence and stability properties of these schemes. For example, an AdamsMoulton scheme always has larger interval of absolute stability than the same order of Adams-Bashforth scheme. • Describe the idea of a Predictor-Corrector (PC) method. State how the accuracy of the PC depends on the orders on the predictor and corrector schemes. • Introduce the idea of a stiff ODE and use the ODE $\acute{y} = \lambda y$ and initial condition Y(0) = y0 to demonstrate the difficulty with stiff equations. • Introduce backward differentiation methods for stiff systems and establish Gear's method.	4	16

Finite Element Method in 1D • Introduce the idea of the variational formulation of a problem. • Introduce the notion of an element and state how the solution of the variational problem is expressed in terms of the elements and demonstrate that the underlying variational problem is uniquely solvable. • Describe the set of tent-functions over a finite dissection of [a,b] and construct all possible inner products of tent functions. Introduce the idea of a reference element and the element mapping and element stiffness matrix. • Show how these components are assembled into a final linear problem. • Discuss how different boundary conditions are incorporated into the procedure. For example, Dirichlet boundary conditions enter through the space of finite elements whereas Neumann boundary conditions enter through the variational formulation of the problem. • Briefly introduce quadratic elements and indicate what changes need to be made to accommodate these elements. • Do several specimen examples involving the solution of linear and nonlinear problems over [0,1] for various choices of boundary condition. Demonstrate the idea that changing the boundary conditions involves minimalist changes to the formulation of the numerical problem	4	16

Spectral and Pseudo-Spectral Methods • Describe the benefits of a spectral approach to the solution of differential equations over finite element, finite difference, Runge-Kutta and multi-step methods. Distinguish between a pseudospectral (or collocation) approach to the solution of a differential equation, a Galerkin spectral approach and a Tau spectral approach. • Introduce the Chebyshev and Legendre families of orthogonal polynomials. Develop basic properties of these polynomial families, and specifically how the derivatives of family members are expressible as spectral series within the family. Explain why these polynomial families allow spectral accuracy if the underlying unknown is arbitrarily smooth. • Use polynomial interpolation to construct the pseudo-spectral differentiation matrix for Chebyshev polynomials. • Develop the Chebyshev transform pair by which function values are determined from Chebyshev spectral coefficients and vice-versa. Indicate how the Chebyshev transform pair can be implemented using the Fast Fourier Transform. • Provide examples in the use of spectral and pseudo-spectral methods in solving, for example, the Diffusion equation and Burger's equation. • Discuss the extension of spectral methods to higher dimensional regions, for example a rectangular region or a disk, or a cylinder.	4	16

2. Course components (total contact hours and credits per semester):

	Lecture	Tutorial	Laboratory or Studio	Practical	Other:	Total
Contact Hours	60	--				60
Credit	4	--				4

3. Additional private study/learning hours expected for students per week.
Four hours weekly for homework and revision

4. Course Learning Outcomes in NQF Domains of Learning and Alignment with Assessment Methods and Teaching Strategy
On the table below are the five NQF Learning Domains, numbered in the left column. **First**, insert the suitable and measurable course learning outcomes required in the appropriate learning domains (see suggestions below the table). **Second**, insert supporting teaching strategies that fit and align with the assessment methods and intended learning outcomes. **Third**, insert appropriate assessment methods that accurately measure and evaluate the learning outcome. Each course learning outcomes, assessment method, and teaching strategy ought to reasonably fit and flow together as an integrated learning and teaching process. (Courses are not required to include learning outcomes from each domain.)

Code #	NQF Learning Domains And Course Learning Outcomes	Course Teaching Strategies	Course Assessment Methods
1.0	**Knowledge** Upon completion of the course, the student is expected to		
1.1	Have knowledge and understanding of various numerical methods (e.g., Taylor, Runge-Kutta, Linear Multi-Step, finite element, Spectral and Pseudo-Spectral Methods) used to solve differential equations problems.	Lectures - Discussions, and homework	Short quizzes, periodical and final exams.
1.2	Be able to integrate related topics from separate parts of the course	Lectures - Discussions, and homework	Short quizzes, periodical and final exams.
2.0	**Cognitive Skills** Upon completion of the course, the student is expected to		
2.1	Be able to follow specialized and application-oriented technical literature in the area	Lectures - Discussions, and homework	Short quizzes, periodical and final exams.
2.2	Formulate and solve relatively complicated mathematical models for real world problems where there is dependence in both time and space.	Lectures - Discussions, and homework	Short quizzes, periodical and final exams.
3.0	**Interpersonal Skills & Responsibility** Upon completion of the course, the student is expected to		
3.1	Effectively work alone and in groups on the solution of problems	Lectures - Discussions, and homework	Short quizzes, periodical and final exams.
3.2	Develop and implement in MATLAB advanced algorithms for solving nonlinear systems of algebraic equations and one and two-dimensional nonlinear	Lectures - Discussions, and homework	Short quizzes, periodical and final exams.

	partial differential equations on regular structured grids		
4.0	**Communication, Information Technology, Numerical** Upon completion of the course, the student is expected to		
4.1	Be able to use commercial software with understanding of fundamental methods, properties, and limitations	Lectures - Discussions, and homework	Short quizzes, periodical and final exams.
4.2	Engage critical, analytical and communication skills though a combination of report writing, group collaboration, individual problem solving and computer programming.	Lectures - Discussions, and homework	Short quizzes, periodical and final exams.
5.0	**Psychomotor**		
5.1	Not applicable	Not applicable	Not applicable

5. Schedule of Assessment Tasks for Students During the Semester			
	Assessment task (e.g. essay, test, group project, examination, speech, oral presentation, etc.)	Week Due	Proportion of Total Assessment
1	Periodic exam (1)	8	20
2	Periodic exam (2)	14	20
3	Home work	During the semester	20
4	Final exam	End of semester	40

D. Student Academic Counseling and Support

1. Arrangements for availability of faculty and teaching staff for individual student consultations and academic advice. (include amount of time teaching staff are expected to be available each week)

The subject's lecturers will be available for individual student consultations and advice in their specified office hours

E Learning Resources

1. List Required Textbooks

- Numerical Methods for Ordinary Differential Equations J.C. Butcher (2003).
- The mathematical theory of finite element methods, S.C. Brenner and R. Scott, 2ed, Springer, 2002.

• Spectral Methods in Fluid Dynamics, C. Canuto, M.Y. Hussaini, A. Quarteroni and T.A. Zang (1988).
2. List Essential References Materials (Journals, Reports, etc.) Journal of Computational and Applied Mathematics
3. List Recommended Textbooks and Reference Material (Journals, Reports, etc)
4. List Electronic Materials, Web Sites, Facebook, Twitter, etc. https://en.wikipedia.org/wiki/Numerical_partial_differential_equations
5. Other learning material such as computer-based programs/CD, professional standards or regulations and software. None

F. Facilities Required

Indicate requirements for the course including size of classrooms and laboratories (i.e. number of seats in classrooms and laboratories, extent of computer access etc.)
1. Accommodation (Classrooms, laboratories, demonstration rooms/labs, etc.) Classroom with the capacity of 10-20 students
2. Computing resources (AV, data show, Smart Board, software, etc.) Smart board. - Classroom is equipped with a computer. - Provide projectors and related items. Matlab software – Smart board
3. Other resources (specify, e.g. if specific laboratory equipment is required, list requirements or attach list) None

G Course Evaluation and Improvement Processes

1 Strategies for Obtaining Student Feedback on Effectiveness of Teaching Student feedback on effectiveness of teaching
2 Other Strategies for Evaluation of Teaching by the Instructor or by the Department Monitoring the achievement of the students in solving homework and periodical exams
3 Processes for Improvement of Teaching Following up the student's homework. Encouraging the students to read and practice more.
4. Processes for Verifying Standards of Student Achievement (e.g. check marking by an independent member teaching staff of a sample of student work, periodic exchange and remarking of tests or a sample of assignments with staff at another institution) The instructors watch and give their feedbacks to their students through all work done by them, including exams to verify standards of achievements for different domains of learning outcomes.
5 Describe the planning arrangements for periodically reviewing course effectiveness

and planning for improvement. Reviewing the course reports submitted at the end of each semester.

Name of Instructor: Dr. Hala Ahmad Hejazi
Signature: Hala Ahmad Hejazi Date Report Completed: 31/10/2018
Name of Field Experience Teaching Staff ______________________________
Program Coordinator:____
Signature: ____________________ Date Received:_______________