Department of: Statistics

College of: Administration & Economics

University of: Salahaddin University - Erbil

Subject: Numerical Analysis with R

Course Book – (Year 2) 2nd Semester

Lecturer's name: Nazeera S. Kareem (PhD)

Academic Year: 2022/2023

Course Book

1. Course name	**Numerical Analysis with R programming language**
2.Lecturer in charge	**Nazeera S.Kareem**
3.Department/ College	**Statistics/ Administration & Economics**
4. Contact	**e-mail: nazeera.kareem@su.edu.krd**

	nazeera.barznji@gmail.com **Tel: (optional) 07504812550**
5. Time (in hours) per week	**Theory: 2 hours** **Practical: 2 hour**
6. Office hours	**15 hours per week**
7. Course code	**SAE104**
8.Teacher's academic profile	• **BSC(Statistics department)(College Administration & Economics) from (The University of Sulaimania)** • **MSC (Statistics department)(College Administration & Economics) from (The University of Salahaddin-Erbil)(2001)** • **PHD (Statistics department)(College Administration & Economics) from the(University of Salahaddin-Erbil) (2015)** • **Assistant researcher(College Administration & Economics)1980** • **Assistant lecturer (The University of Salahaddin -Erbil) (2006)** • **Lecturer(2015)(The University of Salahaddin -Erbil)** • **Assistant Prof.(2019))(The University of Salahaddin -Erbil)** • **Teaching from (16) years at the University of Salahaddin -Erbil)**

	The Subjects that I taught: -Non Parametric Statistical test (Master- Statistics department) -(Numerical Analysis with R Programming language --2nd Stage) (Statistics department) -(Numerical Analysis --2nd Stage) (Statistics department) - (Advanced Statistics--2ndStage) (Economics department) -(Principle of Statistics--1st Stage)(Economics department) -(Principle of Statistics--1stStage) (Administration department) -(Computer- M.S. Excel)-- 2nd Stage) (Administration department) -(Principle of Mathematics--1stStage) (Finance and Banks department) -(Academic Debate --1st Stage) (Statistics department)- -(Methodical Research --4st Stage) (Statistics department)- • **The researches that I had accomplished** 1-PhD (A Dissertation) about [Genetic Effects using R-QTL Statistical Analysis after Chemical Attack on Survivors in Halabja- kurdistan 2- MSC(Thesis) Statistical Study in Analyzing the Chemical Structure of Some Carbonic Rocks in Kurdistan-Iraq

	3- (Women and education)for-conference about the reality of women (in the global women's day) it took 3 days (3 / 11-8 / 2008) 4- (University leadership) in conference the Ministry of Higher Education and Scientific research 2008 5- (Using Entropy in Kurdish poetry(homeland) from poet Fayaq Bekas in work shop for World Statistics Day(20/10/2015) 6- construction robust simple linear regression profile monitoring(Simulation study) (7/3/2017) 7- De-noise data by using Multivariate Wavelets in the Path analysis with application 8-Entropy- in the Kurdish Poetry of poets (Fayaq Bekas) and (Goran) 9-Logistic Regression and Discriminant analysis to identify the risk of Diabetes 10-Constructing mathematical Models, by Interpolation Methods, of people’s interest to listening to Quran’s voice or music 11- تقليل ضوضائية البيانات للتحليل التمييزيباستخدام مويجات متعددة المتغيرات)(محاكاة مع تطبيق عملي) 12-التنبؤبالرقم القياسي ومعدل التضخم لإقليم كوردستان العراق بإستخدام نموذج حركي للشبكات العصبية مع السلاسل الزمنية

	13- Assessing by Model Fitting Criteria and comparing between Stirling and Aitken interpolation formulas to determine the preferred treatment of choice, (surgery) or (surgery with chemotherapy), for lung cancer in Kurdistan 14- Utilizing Cox Regression Analysis and Bootstrapping Test for Indicating the Risk of Smoking on Health in Kurdistan 15- Estimating Parameters and Predicting the Risk of Miscarriage, Infertility, and Psychological Disorders Among Chemical Attack Survivors of Kurdistan by Using Multinomial Logistic Regression Analysis **Languages** -Kurdish the mother language -English -Arabic
9. Keywords	Numerical Analysis with R [Power series, Finite Differences, Interpolation, Numerical Integration and differential equations]and applications on R programming Language for Numerical Analysis

10. Course overview:

Numerical analysis A branch of mathematics/computer science dealing with the study of algorithms for the numerical solution of problems formulated and studied in other branches of mathematics. Numerical Analysis is an applied mathematics technique that allows staggeringly large amount of data to be processed and analyzed for trends, thereby aiding in forming conclusions . Numerical analysis relies on three main components: algorithms,

computing hardware, and computing language. Algorithms usually do not affect the choice of a programming language as they can be implemented in any language. Hardware today plays a role in the selection of a programming language only if they support a particular language in computing, as in the case of GPU's. The choice of a programming language has always been a matter of long-term investment by both researchers and institutions. The open source feature of the R language has encouraged vast adoption by researchers and research institutions (in addition to businesses) and wide and steady contributions from independent package developers. It cannot be understated what impact the existence of learning resources can have on the adoption and growth of a programming language. Computational Methods for Numerical Analysis with R can be considered one of the few resources on numerical analysis algorithms in R language currently on the market. The book starts with simple numerical algorithms and mathematical operations that become more engaging than intimidating to the reader who has little exposure to numerical computing. The transition to more complicated topics remains smooth through clear description of the algorithms, comparisons, and examples. The overall clarity of the book makes it very accessible to self-learners. The book assumes that the reader has knowledge at the level of undergraduate mathematics and the ability to write code in R. Therefore, the explanations of mathematical concepts are brief and more exposition is dedicated to the algorithms and their implementation in R. A prominent feature of the book is the inclusion of exercises at the end of each chapter. The exercises are enough in number and rich enough in scope to help the readers reinforce their understanding of the concepts and further extend them to more advanced and complicated problems. The exercises provide an opportunity for the readers to improve their algorithmic thinking needed for scientific computing. At the time of writing this review, there is no solution for the exercises. In summary, Computational Methods for Numerical Analysis with R provides an excellent introduction to numerical analysis using R for undergraduate students and researchers who prefer to invest in or switch to R for their academic and research

endeavors and also for those students and researchers who need access to a free and rich programming environment. This introductory text clearly shows the potential of R in applied mathematical fields such as optimization, scientific computing, and engineering.

History Numerical algorithms are at least as old as the Egyptian Rhind papyrus (c. 1650 BC), which describes a root-finding method for solving a simple equation. Ancient Greek mathematicians made much further advancement in numerical methods. In particular, Eudoxus of Cnidus (c. 400– 350 BC) created and Archimedes (c. 285–212/211 BC) perfected the method of exhaustion for calculating lengths, areas, and volumes of geometric figures. When used as a method to find approximations, it is in much the spirit of modern numerical integration; and it was an important precursor to the development of calculus by Isaac Newton (1642–1727) and Gottfried Leibniz (1646–1716). Linear interpolation was already in use more than 2000 years ago. Before the advent of modern computers numerical methods often depended on hand interpolation in large printed tables. Since the mid 20th century, computers calculate the required functions instead. Numerical analysis naturally finds applications in all fields of engineering and the physical sciences, but in the 21st century also the life sciences and even the arts have adopted elements of scientific computations. Ordinary differential equations appear in celestial mechanics (planets, stars and galaxies), numerical linear algebra is important for data analysis of stochastic differential equations and Markov chains are essential in simulating living cells for medicine and biology.

11. Course objective:

The overall goal of the field of numerical analysis is the design and analysis of techniques to give approximate but accurate solutions to hard problems, The broad objectives are to learn about existence and uniqueness criteria for numerical methods with R programming Language, to learn about convergences criteria. The specific objectives of the course are the

student should be able to the variety of theorems and mathematical applications which they suggested in the following statements:

1- Apply Taylor and Maclaurian Series to mathematical problems.

3-Use finite differences

4-Interpolations of(Newton forward and Newton backward ,Gaussian) and Lagrange Interpolation.

5-Apply several methods of numerical integration, including[Simpson's Integration and Newton–Cotes formulas integration].

6-Application on R programming Language.

12. Student's obligation

The role of students and their obligations

1-The student attendance to lecture at the time and place as scheduled

by the head of department

2- Preparing the home work

3- Solving the problem(exercise) on the whiteboard by the students

4- The student is ready for the sudden exam on the material is described before (Most of the homework exercises will come after explaining theorems or applications on R).

5- Enquiry the student of topics mysterious and unintelligible in leisure time of lecturer

6- Preparing the student for daily tests (quiz) after clarify and explain Article The main technique will be used in the lectures. At the beginning of each lecture I will inquire students if they were reading the previous lecture by 5 Minutes (quiz).

7-After complementing explaining the lecture I encourage student to ask questions if they are unable to ask their questions in class, then they may ask outside of class in any time I am in the office.

13. Forms of teaching

The course is structured in lectures and exercises in the computer laboratory. More precisely, the lectures on the numerical methods for differential problems described by ordinary or partial differential equations are followed by laboratory exercises aimed at implementing these methods in R and developing an adequate sensitivity and awareness of their use.

To accomplish acceptable outcome the lecturer use several methods to explain and clarify the lecture

1- Power point presentation for, title of theorem, definitions, graph, results general formula, Exercises.

2- Use Data Show to view PowerPoint representation.

2- White board using to prove theories and solutions for examples or exercise**.**

14. Assessment scheme

The exam aims to verify the achievement of the following educational objectives:

- Knowledge of the numerical-mathematical aspects and of the main algorithmic methodologies that deal with the numerical solution
- Ability to solve real problems of interest in numerical methods and writing the corresponding algorithms in R.

The end-of-course exam (the evaluation of which is in thirtieths) will take place in a single test which includes both the development of R codes for the numerical solution of problems, and the written answer to theoretical questions on the topics covered in the lessons.

During the test, the use of support material such as textbooks, notes, computer supports is not allowed.

-Daily students activity(quiz, homework , attendance,)

15. Student learning outcome:

The course includes a laboratory activity in which the R software will be used. The corresponding teaching material will be made available to the student in electronic format and will be downloadable Internet

It is well known that the use of numerical methods for the analysis systems has been increasing at a rapid rate. Therefore, this course is intended to better prepare future computational scientists, in understanding the fundamentals of numerical methods, especially their application, limitations, and potentials. The course will cover the classical fundamental topics in numerical methods the viewpoint will be modern, with connections made between each topic and a variety of applications. By the end of the course, the student should not only be familiar, but more confident, in effectively using numerical tools to solve problems in their own field of interest. In particular, the students will become proficient in: Understanding the theoretical and practical aspects of the use of numerical methods implementing numerical methods for a variety of multidisciplinary applications establishing the limitations, advantages, and disadvantages of numerical methods the expected learning outcomes for the course will be assessed through: Exams, home works, in- class activities and class discussions. In this course, the emphasis will be to apply well-known numerical techniques to solve engineering problems and evaluate the results. The objective will be to train students to understand why the methods work, what type of errors to expect, and when an application might lead to difficulties. In particular, the students will become proficient in:

The expected learning outcomes for the course will be assessed through Exams, home works, in- class activities and class discussions. 1.Understanding the theoretical and practical aspects of the use of numerical methods

2.Implementing numerical methods for a variety of multidisciplinary applications

3.Establishing the limitations, advantages, and disadvantages of numerical methods

4. The students should be able to select from alternative methods the one method that is most appropriate for a specific problem.

5. The students should be able to formulate algorithms to solve problems numerically.

6. They should understand the limitations of each numerical method, especially the conditions under which they fail to converge to a solution. The use of Numerical analysis and mathematical modeling have become essential in many areas of modern life in the list of immense and extends across most major disciplines and fields of work. 1-Advanced numerical methods are essential in making numerical weather prediction feasible. weather, monitor climate change,

2-It is used to predict pick out stock market trends, compute actuarial data Insurance companies use numerical programs for actuarial analysis.

3- Computing the trajectory of a spacecraft requires the accurate numerical solution of a system of ordinary differential equations.

4- Car companies can improve the crash safety of their vehicles by using computer simulations of car crashes. Such simulations essentially consist of solving partial differential equations numerically.

5- Hedge funds (private investment funds) use tools from all fields of numerical analysis to attempt to calculate the value of stocks and derivatives more precisely than other market participants.

6- Airlines use sophisticated optimization algorithms to decide ticket prices, airplane and crew assignments and fuel needs. Historically, such algorithms were developed within the overlapping field of operations research.

7- Numerical Analysis is an applied mathematics technique that allows staggeringly large amount of data to be processed and analyzed for trends, thereby aiding in forming conclusions providing massive increases in speed and usefulness of calculations.

8- Ordinary differential equations appear in celestial mechanics (planets, stars and galaxies)

16. Course Reading List and References:

▪ Key references:

1- An Introduction to numerical analysis, by A.S. ELALOOSY

2- Introduction to Numerical Analysis by Oron Levy ,(September 21th , 2010)

3- Atkinson K , an introduction to numerical analysis , second edition John , Willy

4- Introduction to approximation theory , second edition Chelsea publishing company

5- Analysis of Numerical Methods, Isaacson E, Keller H.B, Second edition , Dover , Mineola

6- Analysis of Numerical Analysis ,Stoer J. Burlisch .R , second edition, Verlag , New York

7- Schaum Outline Theory and Problems of Numerical Analysis

8- Schaum's Outline of Numerical Analysis - Powell's Books

9-By Alexander Paprotny Real time Data Mining: Self-Learning Techniques for Recommendation Engines (Applied and Numerical Analysis (1st ed. 2013.)

10-A Concise Introduction to Numerical Analysis Douglas N. Arnold ,School of Mathematics, University of Minnesota, Minneapolis, MN 55455 ▪

Useful references:

[Cra-11] Crawley, M. J. (2011), The R Book, John Wiley.

[Gri-11] Griffiths,G.W. and W. E. Schiesser (2011),Traveling Wave Solutions of Partial Differential Equations: Numerical and Analytical Methods with Matlab and Maple, Academic Press.

[Mat-11] Matloff, N. (2011), The Art of R Programming, No Starch Press. [Sch-09] Schiesser, W. E. and G. W. Griffiths (2009), A Compendium of Partial Differential Equation Models: Method of Lines Analysis with Matlab, Cambridge University Press.

[Soe-10] Soetaert, K., T. Petzoldt and R. W. Setzer (2010), Solving Differential Equations in R: Package deSolve, Journal of Statistical Software 33-9, 1–25.

[Soe-12] Soetaert, K., J. Cash and F. Mazzia (2012), Solving Differential Equations in R, Springer

Magazines and review (internet):

1-numerical analysis A Dictionary of Computing | 2004 | JOHN DAINTITH | originally published by Oxford University Press 2004

2-A Review of JMP 4.03 with Special Attention to Its Numerical Accuracy Magazine article from: The American Statistician

3-SIAM Journal on Numerical Analysis one year (6 issues) for €1,077.50 publisher: SIAM Society for Industrial and Applied Related: Mathematics

4-International Journal for Numerical Methods in Engineering Impact Factor & Information Publisher: Wiley

5-The International Magazine Specialist! Write a review for Applied Numerical Analysis

17. The Topics:	**Lecturer's name**
Chapter One **1-Power Series [Power Expansion]** 1-1 The Remainder of Taylor series [Taylor Expansion] [Proof and Example] 1-2 Euler's formula [Relation between Maclaurian expansion and Polar form] (Proof) **Exercises**	2weeks

1-3 R programming language application	
Chapter Two **2- Finite Differences** 2-1Descending Differences[Forward Differences] [Proof and Example] 2-1-1 Table of Descending Differences [Forward Differences] [Proof and Example] 2-1-2 Error Propagation [Proof and Example] 2-2Ascending Differences [Backward Differences] [Proof and Example] 2-2-1Table of Descending Difference[Backward Differences] 2-3 Central Differences [Proof and Example] 2-3-1 Table of Central Differences [Proof and Example] 2-4 Relation between Central Differences and(forward Differences and Backward Differences) or Effect of Central Difference on Forward Difference (Proof) **Exercises** 2-5 R programming language application	3weeks
Chapter T hree **3- Interpolation:** 3-1 What is Interpolation? 3-2Newton's Forward Interpolation Formula{N.F.W.I.F.} [Proof and Example] 3-3Newton's Backward Interpolation Formula {N.B.W.I.F.} [Proof and Example]	6 weeks

3-4 Gaussian Forward of the Interpolation Formula[Proof and Example] 3-5 Gaussian Backward of the Interpolation Formula [Proof and Example] 3-5The Lagrange Form of the Interpolation Formula [Proof and Example] **Exercises** 3-6 R programming language application	
Chapter Four 4- Numerical Integration 4-1 Basic Concepts. 4-2Composite Integration Rules 4-3 Integration via Interpolation 4-4 Methods 4-4-1 Newton–Cotes formulas [Proof and Example] 4-4-2 Simpson's Integration [Proof and Example] **Exercises** 4-4-3 R programming language application	4weeks

19. Examinations:

(Practical) This type of tests are depend on the basis that the questions include practical issues on R programming language to be resolved based on the theories and equations which will be used by students through

20. Extra notes:

Add paragraph about the existence of scientific and intellectual relationship between the lecturers of the same lecture in different colleges to develop curriculum and exchange ideas about what is happening in the scientific and intellectual developments.
21. Peer review: