

# NUMERICAL METHODS

C / KAPPA EXAM 12 / 11/14 / 2022 / 20.00%

## LEAST SQUARES REGRESSION

Goal: minimize the sum of the square of the residual (error).

Residual =  $y_i - \hat{y}_i$

Sum of Squares =  $\sum (y_i - \hat{y}_i)^2$

Minimize:  $\sum (y_i - \hat{y}_i)^2$

Model:  $\hat{y}_i = a_0 + a_1 x_i$

Normal Equations:

$$\sum y_i = \sum (a_0 + a_1 x_i)$$

$$\sum x_i y_i = \sum x_i (a_0 + a_1 x_i)$$

$$\sum y_i = n a_0 + a_1 \sum x_i$$

$$\sum x_i y_i = a_0 \sum x_i + a_1 \sum x_i^2$$

$$\sum y_i^2 = \sum (a_0 + a_1 x_i)^2$$

$$\frac{\partial S}{\partial a_0} = 0$$

$$\frac{\partial S}{\partial a_1} = 0$$

$$S = \sum (y_i - a_0 - a_1 x_i)^2$$

$$\frac{\partial S}{\partial a_0} = -2 \sum (y_i - a_0 - a_1 x_i) = 0$$

$$\frac{\partial S}{\partial a_1} = -2 \sum x_i (y_i - a_0 - a_1 x_i) = 0$$

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## STANDARD ERROR:

$$S_y = \sqrt{\frac{\sum (y_i - \hat{y}_i)^2}{n-2}}$$

## STANDARD DEVIATION:

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## INTERPOLATION

Use a polynomial fit:

Linear:  $y = a_0 + a_1 x$

Quadratic:  $y = a_0 + a_1 x + a_2 x^2$

Cubic:  $y = a_0 + a_1 x + a_2 x^2 + a_3 x^3$

Polynomial:  $y = a_0 + a_1 x + a_2 x^2 + \dots + a_n x^n$

Order:  $n = 1, 2, 3, \dots$

Turns:  $n = 1, 2, 3, \dots$

Spines:  $n = 1, 2, 3, \dots$

ODE's

Euler's Method:

$$y_{i+1} = y_i + f(x_i, y_i) \Delta x$$

Runge-Kutta Method:

$$y_{i+1} = y_i + f(x_i, y_i) \Delta x$$

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Taylor Series:  
 $y(x) = y_0 + y'_0 x + \frac{y''_0}{2!} x^2 + \dots$   
 $y(x) = y_0 + y'_0 x + \frac{y''_0}{2!} x^2 + \dots$

## CLASSIC 4th ORDER RUNGE-KUTTA

$$y_{i+1} = y_i + \frac{\Delta x}{4} (k_1 + 2k_2 + 2k_3 + k_4)$$

$$k_1 = f(x_i, y_i)$$

$$k_2 = f(x_i + \frac{\Delta x}{2}, y_i + \frac{\Delta x}{2} k_1)$$

$$k_3 = f(x_i + \frac{\Delta x}{2}, y_i + \frac{\Delta x}{2} k_2)$$

$$k_4 = f(x_i + \Delta x, y_i + \Delta x k_3)$$

Forward Time, Backward Space

$$y_{i+1} = y_i + \Delta x \frac{dy}{dx}$$

$$y_{i+1} = y_i + \Delta x \frac{dy}{dx}$$

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## PDE'S

### FINITE DIFFERENCE METHOD

Grid spacing:  $\Delta x, \Delta y$

Central Difference:

Forward Difference:

Backward Difference:

Time step:  $\Delta t$

Stability:  $\Delta t \leq \frac{\Delta x^2}{2\alpha}$

Accuracy:  $\Delta t \propto \Delta x^2$

Convergence:  $\Delta t \propto \Delta x^2$

Consistency:  $\Delta t \propto \Delta x^2$

Stability:  $\Delta t \leq \frac{\Delta x^2}{2\alpha}$

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## EIGEN VALUES

1. Eigen value

Example:  $A = \begin{bmatrix} 1 & 2 \\ 2 & 1 \end{bmatrix}$

$$A - \lambda I = \begin{bmatrix} 1-\lambda & 2 \\ 2 & 1-\lambda \end{bmatrix}$$

$$\det(A - \lambda I) = 0$$

$$(1-\lambda)^2 - 4 = 0$$

$$\lambda^2 - 2\lambda - 3 = 0$$

$$(\lambda - 3)(\lambda + 1) = 0$$

$$\lambda = 3, -1$$

$$\lambda = 3, -1$$

$$\lambda = 3, -1$$

$$\lambda = 3, -1$$

$$\lambda = 3, -1$$

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# Numerical Methods And Analysis

**Clemente Cesarano**



## **Numerical Methods And Analysis:**

**An Introduction to Numerical Methods and Analysis** James F. Epperson, 2021-07-21 The new edition of the popular introductory textbook on numerical approximation methods and mathematical analysis with a unique emphasis on real world application An Introduction to Numerical Methods and Analysis helps students gain a solid understanding of a wide range of numerical approximation methods for solving problems of mathematical analysis Designed for entry level courses on the subject this popular textbook maximizes teaching flexibility by first covering basic topics before gradually moving to more advanced material in each chapter and section Throughout the text students are provided clear and accessible guidance on a wide range of numerical methods and analysis techniques including root finding numerical integration interpolation solution of systems of equations and many others This fully revised third edition contains new sections on higher order difference methods the bisection and inertia method for computing eigenvalues of a symmetric matrix a completely re written section on different methods for Poisson equations and spectral methods for higher dimensional problems New problem sets ranging in difficulty from simple computations to challenging derivations and proofs are complemented by computer programming exercises illustrative examples and sample code This acclaimed textbook Explains how to both construct and evaluate approximations for accuracy and performance Covers both elementary concepts and tools and higher level methods and solutions Features new and updated material reflecting new trends and applications in the field Contains an introduction to key concepts a calculus review an updated primer on computer arithmetic a brief history of scientific computing a survey of computer languages and software and a revised literature review Includes an appendix of proofs of selected theorems and a companion website with additional exercises application models and supplemental resources An Introduction to Numerical Methods and Analysis Third Edition is the perfect textbook for upper level undergraduate students in mathematics science and engineering courses as well as for courses in the social sciences medicine and business with numerical methods and analysis components

**Analysis of Numerical Methods** Eugene Isaacson, Herbert Bishop Keller, 2012-04-26 This excellent text for advanced undergraduate and graduate students covers norms numerical solutions of linear systems and matrix factoring eigenvalues and eigenvectors polynomial approximation and more Many examples and problems 1966 edition

**An Introduction to Numerical Methods and Analysis, Solutions Manual** James F. Epperson, 2014-08-28 A solutions manual to accompany An Introduction to Numerical Methods and Analysis Second Edition An Introduction to Numerical Methods and Analysis Second Edition reflects the latest trends in the field includes new material and revised exercises and offers a unique emphasis on applications The author clearly explains how to both construct and evaluate approximations for accuracy and performance which are key skills in a variety of fields A wide range of higher level methods and solutions including new topics such as the roots of polynomials spectral collocation finite element ideas and Clenshaw Curtis quadrature are presented from an introductory perspective and the Second Edition also features Chapters and

sections that begin with basic elementary material followed by gradual coverage of more advanced material Exercises ranging from simple hand computations to challenging derivations and minor proofs to programming exercises Widespread exposure and utilization of MATLAB An appendix that contains proofs of various theorems and other material

**Numerical Methods and Analysis** James L. Buchanan, Peter R. Turner, 1992 Intended for a first course in numerical methods or numerical analysis taken by junior and senior level students this book assumes a knowledge of calculus linear algebra and differential equations It covers numerical approximation interpolation graphics and parallel computing The interplay between hardware and software considerations in numerical algorithm design recurs throughout A portion of the programs in the book are written in Turbo Pascal the remainder are pseudocode or generalized algorithms Programs used in the text will be available on a disk for instructors to use and copy

*Numerical Analysis* M. Schatzman, 2002 Numerical analysis explains why numerical computations work or fail This book is divided into four parts Part I starts with a guided tour of floating number systems and machine arithmetic The exponential and the logarithm are constructed from scratch to present a new point of view on questions well known to the reader and the needed knowledge of linear algebra is summarized Part II starts with polynomial approximation polynomial interpolation mean square approximation splines It then deals with Fourier series providing the trigonometric version of least square approximations and one of the most important numerical algorithms the fast Fourier transform Any scientific computation program spends most of its time solving linear systems or approximating the solution of linear systems even when trying to solve non linear systems Part III is therefore about numerical linear algebra while Part IV treats a selection of non linear or complex problems resolution of linear equations and systems ordinary differential equations single step and multi step schemes and an introduction to partial differential equations The book has been written having in mind the advanced undergraduate students in mathematics who are interested in the spice and spirit of numerical analysis The book does not assume previous knowledge of numerical methods It will also be useful to scientists and engineers wishing to learn what mathematics has to say about the reason why their numerical methods work or fail

*An Introduction to Numerical Analysis, 2nd Ed* Kendall E. Atkinson, 2008-09

Market\_Desc Mathematics Students Instructors About The Book This Second Edition of a standard numerical analysis text retains organization of the original edition but all sections have been revised some extensively and bibliographies have been updated New topics covered include optimization trigonometric interpolation and the fast Fourier transform numerical differentiation the method of lines boundary value problems the conjugate gradient method and the least squares solutions of systems of linear equations

*Solutions Manual to accompany An Introduction to Numerical Methods and Analysis* James F. Epperson, 2013-10-21 A solutions manual to accompany *An Introduction to Numerical Methods and Analysis* Second Edition *An Introduction to Numerical Methods and Analysis* Second Edition reflects the latest trends in the field includes new material and revised exercises and offers a unique emphasis on applications The author clearly explains how to both

construct and evaluate approximations for accuracy and performance which are key skills in a variety of fields A wide range of higher level methods and solutions including new topics such as the roots of polynomials spectral collocation finite element ideas and Clenshaw Curtis quadrature are presented from an introductory perspective and the Second Edition also features Chapters and sections that begin with basic elementary material followed by gradual coverage of more advanced material Exercises ranging from simple hand computations to challenging derivations and minor proofs to programming exercises Widespread exposure and utilization of MATLAB An appendix that contains proofs of various theorems and other material

**Theory and Applications of Numerical Analysis** G. M. Phillips, Peter J. Taylor, 1996-07-05 Theory and Applications of Numerical Analysis is a self contained Second Edition providing an introductory account of the main topics in numerical analysis The book emphasizes both the theorems which show the underlying rigorous mathematics and the algorithms which define precisely how to program the numerical methods Both theoretical and practical examples are included a unique blend of theory and applications two brand new chapters on eigenvalues and splines inclusion of formal algorithms numerous fully worked examples a large number of problems many with solutions

**Numerical Methods for Ordinary Differential Equations** J. C. Butcher, 2008-04-15 In recent years the study of numerical methods for solving ordinary differential equations has seen many new developments This second edition of the author's pioneering text is fully revised and updated to acknowledge many of these developments It includes a complete treatment of linear multistep methods whilst maintaining its unique and comprehensive emphasis on Runge Kutta methods and general linear methods Although the specialist topics are taken to an advanced level the entry point to the volume as a whole is not especially demanding Early chapters provide a wide ranging introduction to differential equations and difference equations together with a survey of numerical differential equation methods based on the fundamental Euler method with more sophisticated methods presented as generalizations of Euler Features of the book include Introductory work on differential and difference equations A comprehensive introduction to the theory and practice of solving ordinary differential equations numerically A detailed analysis of Runge Kutta methods and of linear multistep methods A complete study of general linear methods from both theoretical and practical points of view The latest results on practical general linear methods and their implementation A balance between informal discussion and rigorous mathematical style Examples and exercises integrated into each chapter enhancing the suitability of the book as a course text or a self study treatise Written in a lucid style by one of the world's leading authorities on numerical methods for ordinary differential equations and drawing upon his vast experience this new edition provides an accessible and self contained introduction ideal for researchers and students following courses on numerical methods engineering and other sciences

*Numerical Analysis or Numerical Method in Symmetry* Clemente Cesarano, 2020-02-21 This Special Issue focuses mainly on techniques and the relative formalism typical of numerical methods and therefore of numerical analysis more generally These fields of study of mathematics represent an important field of investigation both in the field of applied

mathematics and even more exquisitely in the pure research of the theory of approximation and the study of polynomial relations as well as in the analysis of the solutions of the differential equations both ordinary and partial derivatives Therefore a substantial part of research on the topic of numerical analysis cannot exclude the fundamental role played by approximation theory and some of the tools used to develop this research In this Special Issue we want to draw attention to the mathematical methods used in numerical analysis such as special functions orthogonal polynomials and their theoretical tools such as Lie algebra to study the concepts and properties of some special and advanced methods which are useful in the description of solutions of linear and nonlinear differential equations A further field of investigation is dedicated to the theory and related properties of fractional calculus with its adequate application to numerical methods **Applied Numerical Analysis** Curtis F. Gerald, Patrick O. Wheatley, 1984 **Numerical Methods and Analysis of Multiscale Problems**

Alexandre L. Madureira, 2017-02-15 This book is about numerical modeling of multiscale problems and introduces several asymptotic analysis and numerical techniques which are necessary for a proper approximation of equations that depend on different physical scales Aimed at advanced undergraduate and graduate students in mathematics engineering and physics or researchers seeking a no nonsense approach it discusses examples in their simplest possible settings removing mathematical hurdles that might hinder a clear understanding of the methods The problems considered are given by singular perturbed reaction advection diffusion equations in one and two dimensional domains partial differential equations in domains with rough boundaries and equations with oscillatory coefficients This work shows how asymptotic analysis can be used to develop and analyze models and numerical methods that are robust and work well for a wide range of parameters

*Numerical Analysis or Numerical Method in Symmetry* Clemente Cesarano, 2020 This Special Issue focuses mainly on techniques and the relative formalism typical of numerical methods and therefore of numerical analysis more generally These fields of study of mathematics represent an important field of investigation both in the field of applied mathematics and even more exquisitely in the pure research of the theory of approximation and the study of polynomial relations as well as in the analysis of the solutions of the differential equations both ordinary and partial derivatives Therefore a substantial part of research on the topic of numerical analysis cannot exclude the fundamental role played by approximation theory and some of the tools used to develop this research In this Special Issue we want to draw attention to the mathematical methods used in numerical analysis such as special functions orthogonal polynomials and their theoretical tools such as Lie algebra to study the concepts and properties of some special and advanced methods which are useful in the description of solutions of linear and nonlinear differential equations A further field of investigation is dedicated to the theory and related properties of fractional calculus with its adequate application to numerical methods INTRODUCTORY METHODS OF NUMERICAL ANALYSIS, FIFTH EDITION SASTRY, S. S., 2012-06-12 This thoroughly revised and updated text now in its fifth edition continues to provide a rigorous introduction to the fundamentals of numerical methods required in scientific and

technological applications emphasizing on teaching students numerical methods and in helping them to develop problem solving skills While the essential features of the previous editions such as References to MATLAB IMSL Numerical Recipes program libraries for implementing the numerical methods are retained a chapter on Spline Functions has been added in this edition because of their increasing importance in applications This text is designed for undergraduate students of all branches of engineering NEW TO THIS EDITION Includes additional modified illustrative examples and problems in every chapter Provides answers to all chapter end exercises Illustrates algorithms computational steps or flow charts for many numerical methods Contains four model question papers at the end of the text      **Introduction to Precise Numerical**

**Methods** Oliver Aberth, 2007-04-11 Precise numerical analysis may be defined as the study of computer methods for solving mathematical problems either exactly or to prescribed accuracy This book explains how precise numerical analysis is constructed The book also provides exercises which illustrate points from the text and references for the methods presented Clearer simpler descriptions and explanations of the various numerical methods Two new types of numerical problems accurately solving partial differential equations with the included software and computing line integrals in the complex plane

An Introduction to Numerical Methods and Analysis Set James F. Epperson, 2013-10-09 This set includes An Introduction to Numerical Methods and Analysis 2nd Edition Roots of Polynomials I Radial Basis Function Interpolation Tension Splines An Introduction to Galerkin Finite Element Ideas for BVPs Broyden's Method Roots of Polynomials II Spectral collocation methods for PDEs Algebraic Multigrid Method Trigonometric interpolation Fourier analysis and Monte Carlo methods

Numerical Analysis Brian Sutton, 2019-04-18 This textbook develops the fundamental skills of numerical analysis designing numerical methods implementing them in computer code and analyzing their accuracy and efficiency A number of mathematical problems interpolation integration linear systems zero finding and differential equations are considered and some of the most important methods for their solution are demonstrated and analyzed Notable features of this book include the development of Chebyshev methods alongside more classical ones a dual emphasis on theory and experimentation the use of linear algebra to solve problems from analysis which enables students to gain a greater appreciation for both subjects and many examples and exercises Numerical Analysis Theory and Experiments is designed to be the primary text for a junior or senior level undergraduate course in numerical analysis for mathematics majors Scientists and engineers interested in numerical methods particularly those seeking an accessible introduction to Chebyshev methods will also be interested in this book      Numerical Methods in Finite Element Analysis Klaus-Jürgen Bathe, Edward L. Wilson, 1976      Numerical Analysis

of Wavelet Methods A. Cohen, 2003-04-29 Since their introduction in the 1980's wavelets have become a powerful tool in mathematical analysis with applications such as image compression statistical estimation and numerical simulation of partial differential equations One of their main attractive features is the ability to accurately represent fairly general functions with a small number of adaptively chosen wavelet coefficients as well as to characterize the smoothness of such functions from the

numerical behaviour of these coefficients The theoretical pillar that underlies such properties involves approximation theory and function spaces and plays a pivotal role in the analysis of wavelet based numerical methods This book offers a self contained treatment of wavelets which includes this theoretical pillar and its applications to the numerical treatment of partial differential equations Its key features are 1 Self contained introduction to wavelet bases and related numerical algorithms from the simplest examples to the most numerically useful general constructions 2 Full treatment of the theoretical foundations that are crucial for the analysis of wavelets and other related multiscale methods function spaces linear and nonlinear approximation interpolation theory 3 Applications of these concepts to the numerical treatment of partial differential equations multilevel preconditioning sparse approximations of differential and integral operators adaptive discretization strategies

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