

# Scientific Computations: Numerical Analysis

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# Unit Overview

- 1 What is Numerical Analysis?
- 2 Why Numerical Analysis?
- 3 Course Contents– Theory
- 4 Practice Lab Classes: MATLAB Software
- 5 Unit Objectives, Recommended Resources, Unit Assessment, Office Hours & Contact Information

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# What is Numerical Analysis?

- Exact solutions are often either **too cumbersome** or **simply do not exist**, or **impossible to obtain in practice**, so **we need to find an approximate method of solution**.
  - ▶ This is where **NUMERICAL ANALYSIS** comes into the picture.
- ***Numerical analysis does not seek exact answers***; instead, much of numerical analysis is concerned with **obtaining approximate solutions through numerical/computational methods/algorithms**.
- ***Numerical analysis seeks to analyze the errors produced by numerical algorithms by identifying their nature and quantity***. Usually the true size of the computational error is **unknown**, so numerical analysis seeks to **provide reasonable (realistic) bound on the error**; i.e. ***the worst case scenario***.

# What is Numerical Analysis?

The desirable characteristics that a numerical algorithm should possess, in no particular order of importance, are:

- 1 **Reliability**: always works correctly for easy problems.
- 2 **Robustness**: usually works for hard problems, but fails gracefully and informatively when it does fail.
- 3 **Accuracy**: produces results as accurate as warranted by the problem and input data, preferably with an estimate of the accuracy achieved.
- 4 **Stability**: a slight perturbation in the input data does not lead to a quite significant effect on the output; i.e. it does not magnify input data errors.
- 5 **Efficiency**: requires execution time and storage that are close to the minimum possible for the problem being solved.
- 6 **Maintainability**: is easy to understand and modify.
- 7 **Portability**: adapts with little or no change to new computing environments.
- 8 **Usability**: has a convenient and well-documented user interface.
- 9 **Applicability**: solves a broad range of problems.

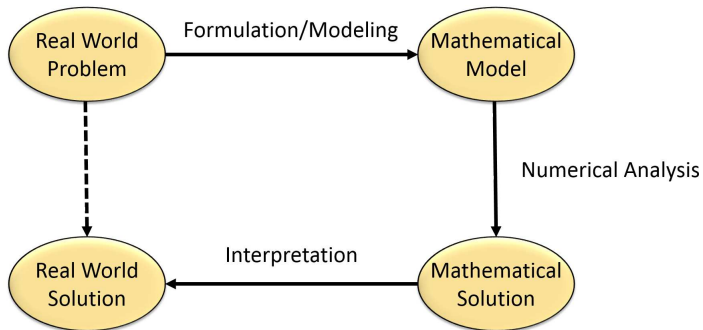
# What is Numerical Analysis?

## Definition 1 (NUMERICAL ANALYSIS)

**Numerical analysis** is the branch of mathematics concerned with the *creation, analysis*, and *implementation of algorithms* to obtain numerical solutions to problems whose exact solutions are either impossible or infeasible to determine (such problems arise throughout the natural sciences, engineering, medicine, business, etc.). In addition to the approximate solution, a *realistic bound* is needed for the error associated with the approximate solution.

# What is Numerical Analysis?

- Typically, a mathematical model for a particular problem, generally consisting of mathematical equations with constraint conditions, is constructed by specialists in the area concerned with the problem. Numerical analysis is concerned with devising methods for approximating the solution to the model, and analyzing the results for accuracy, stability, speed of implementation, computational cost, etc.



# What is Numerical Analysis?

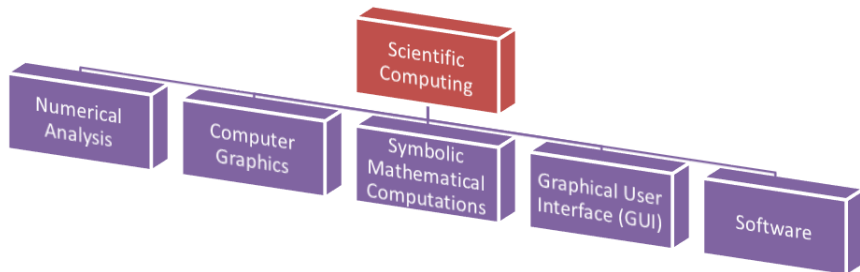
- Numerical analysis has a long history. In fact, the field of numerical analysis predates the invention of modern computers by many centuries. For instances, the popular Rhind Mathematical Papyrus of the Egyptians, the Method of Exhaustion of Archimedes, and how did the Babylonians find approximations to square roots mark the birth of numerical analysis many centuries ago.
- Modern numerical analysis developed quickly and on many fronts with the advent of digital computers. With the growth in importance of using computers to carry out numerical procedures in solving mathematical models of the world, an area known as **scientific computing (scientific computations or computational science)** has taken shape during the 1980s and 1990s.



# What is Numerical Analysis?

## Definition 2 (Scientific Computing)

**Scientific computing** is the area of science which looks at the use of numerical analysis from a computer science perspective. The subject is broad and multi-disciplinary, and it is concerned with using the most powerful tools of **numerical analysis**, **computer graphics**, **symbolic mathematical computations**, **GUI**, and **software** to make it easier for a user to set up, solve, and interpret complicated mathematical models of the real world.



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# Why Numerical Analysis?

Numerical analysis has become essential in many areas of modern life. Some of the most important problems which are encountered in various fields of mathematics, physics, computer science, mechanics, chemistry, biology, economics, and numerous applications, and can be solved by numerical analysis are:

- **Algebraic/Transcendental Equations.**
- **Curve Fitting/Interpolation Problems.**
- **Numerical Differentiation and Integration Problems.**
- **Initial-Value Problems for Ordinary Differential Equations (ODEs).**
- **Boundary-Value Problems for ODEs.**
- **Partial Differential Equations.**
- **Calculating Eigenvalues and Eigenvectors.**
- **Optimization Problems, etc.**

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# Course Contents– Theory

This course is intended as a first introduction to numerical analysis using MATLAB Software; hence this course is not comprehensive and does not cover all of numerical analysis topics. The chapters of the course are as follows:

- **Chapter 1 *Error Analysis***
- **Chapter 2 *Numerical Solution of Nonlinear Equations***
- **Chapter 3 *Finite Differences & Interpolation***
- **Chapter 4 *Curve Fitting: Least Squares Approximation***
- **Chapter 5 *Numerical Differentiation***
- **Chapter 6 *Numerical Integration***
- **Chapter 7 *Solving Sets of Linear Algebraic Equations***
- **Chapter 8 *Initial Value Problems***

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# Practice Lab Classes: Numerical Analysis Using MATLAB

- MATLAB (@ The Mathworks, Inc.) provides a great environment for our course. **It is an integrated technical computing environment that combines numeric computation, advanced graphics and visualization, and a high level programming language.** The classes will focus on teaching the basics of MATLAB as well as how to use it to solve many problems encountered through the course.

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See the PDF file titled “2015 Unit Guide”. The file can be accessed through your student account on <https://www.easyclass.com/>.

**Next Week**

# **CHAPTER 1: ERROR ANALYSIS**