

# MA 1018: Introduction to Scientific Computing Syllabus and Introduction



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# Syllabus

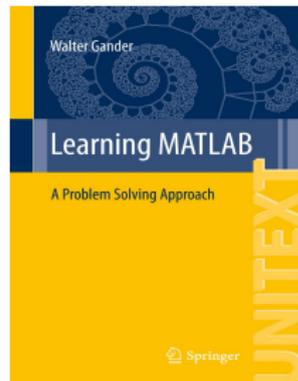
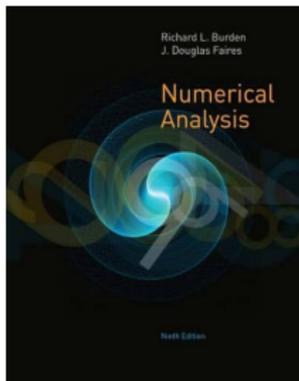
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- **Instructor:** Prof. Suh-Yuh Yang (楊肅煜)
  - Office: M315, Hong-Jing Hall
  - Phone: 03-4227151 ext. 65130
- **Office hours:** Tuesday 10:00 ~ 11:50 am or by appointment.
- **Teaching assistant:** 饒祥弘 / E-mail: 113221006@cc.ncu.edu.tw
- **Prerequisites:** Calculus, Linear Algebra, and some knowledge of a high level programming language MATLAB
- **Homeworks:** Approximately every two weeks, will consist of theoretical problems or computer projects.
- **Examinations:** there will be a midterm and a final.
- **Grading policy:** homeworks 30%, midterm 30%, final 30%, and others 10%.

## Textbook

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**Richard L. Burden and J. Douglas Faires**, *Numerical Analysis*, 9th Edition, Thomson Brooks/Cole, 2011.



**Walter Gander**, *Learning MATLAB: A Problem Solving Approach*, Springer International Publishing Switzerland, 2015.

## Important dates

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- The period for adding and dropping a course: 2/20-3/10, 2026
- The period for withdrawing a course: 4/7-5/15, 2026
- Spring break 4/6 (Mon): **recess, no class!**
- Midterm: 4/13 (Mon), 2026
- Final exam: 6/8 (Mon), 2026

## Scientific computing (科學計算) vs. Numerical analysis

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- **Problem modelling**
  - physical phenomena: too expensive to perform all tests with prototypes.
  - mathematical model (differential or integral equations): too complex or very difficult for paper/pencil solution.
  - computational model (numerical methods): approximation of mathematical model.
- **Scientific computing**: solving mathematical problems numerically on the computer (methods/constructive proofs → algorithms → codes → display).
- **Numerical analysis – mathematics of scientific computing**: it involves the study, development and analysis of algorithms (procedures) for obtaining numerical solutions to various mathematical problems.
- **Scientific computing: interdisciplinary (跨學科)**  
science/engineering; numerical analysis; computer science; software engineering.

## This course will cover the following topics

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- Mathematical preliminaries and basics of Matlab
- Solutions of nonlinear equations
- Interpolation and polynomial approximation
- Numerical differentiation and integration
- Additional topics and applications

## Topic 1: Mathematical preliminaries

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- **Review of calculus**
- **Taylor's Theorem:** for functions in single or several variables
- **Rate of convergence:** big  $O$  notation

## Topic 2: Solutions of nonlinear equations

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- **Question:** given a function  $f : \mathbb{R} \rightarrow \mathbb{R}$ . Find a point  $x^* \in \mathbb{R}$  such that

$$f(x^*) = 0.$$

- If  $f(x)$  is simple, such as  $f(x) = 3x + 1$  or  $f(x) = 3x^2 - 4x + 1$ , then one can use the root formulas. In general, one has to find the root(s) numerically.
- We will study
  - iterative methods for finding the root (bisection method, secant method, Newton type methods);
  - convergence of the methods;
  - extension to systems of nonlinear equations.

## Topic 3: Interpolation and polynomial approximation

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- **Lagrange interpolation (多項式插值)**

We are given  $n + 1$  data points  $(x_i, y_i)$ ,  $i = 0, 1, \dots, n$ , where  $y_i = f(x_i)$  for some function  $f$ . We seek a polynomial  $p$  such that  $p(x_i) = y_i$ ,  $0 \leq i \leq n$ .

- **Hermite interpolation**

It discusses the interpolation of a function and some of its derivatives at a set of nodes, e.g., find a polynomial  $p$  such that  $p(x_i) = f(x_i)$  and  $p'(x_i) = f'(x_i)$ ,  $i = 0, 1$ .

- **Spline (樣條) interpolation**

A spline function of degree  $k$  is a piecewise polynomial of degree at most  $k$  having continuous derivatives of all orders up to  $k - 1$ .

## Topic 4: Numerical differentiation and integration

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- **Numerical differentiation**

- Based on Taylor's theorem: for example,

$$f(x+h) = f(x) + hf'(x) + \frac{h^2}{2}f''(\xi),$$

for some  $\xi$  between  $x$  and  $x+h$ .

- Based on polynomial interpolation: let  $p$  be the Lagrange interpolation of  $f$ . Then  $f'(x) \approx p'(x)$ .

- **Numerical integration based on interpolation**

Let  $p$  be the Lagrange interpolation of  $f$ :  $\int_a^b f(x) dx \approx \int_a^b p(x) dx$ .

- **Gaussian quadrature (高斯積分法)**

Find  $A_i$  and  $x_i, i = 0, 1, \dots, n$ , such that  $\int_a^b f(x) dx \approx \sum_{i=0}^n A_i f(x_i)$

and it will be exact for polynomials of degree  $\leq 2n+1$ .

## Topic 5: Additional topics and applications

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A brief introduction to the following topics:

- **Computational science:** numerical methods for differential equations, computational fluid dynamics (CFD), etc.
- **Mathematical image processing:** variational image processing methods, computer vision, etc.
- **Data science:** clustering, classification, dimensionality reduction, and related machine learning techniques, etc.