Lecture 1: Introduction

MATH 303 ODE and Dynamical Systems

Konstantinos Efstathiou

Who am I?

- Dr. Konstantinos Efstathiou
- I come from Greece 🇬🇷, I did my PhD in France 🇫🇷, and then I worked for several years in the Netherlands 🇳🇱, before coming to China 🇨🇳.
- I now live in Suzhou with my family 👨‍👩‍👦‍👦.
- My research is on **dynamical systems**.
- I love teaching this course not because I know everything about differential equations and dynamical systems (nobody does) but because, every time I teach it, I learn or re-learn something or get the opportunity to improve how I teach these concepts.
- Questions?

Who are you?

- Take 3 minutes and write down a self-introduction.
  - A few words about yourselves, why you are in this course, and what you expect to get out of it. If you are in this course only because this is a major requirement then why did you choose this major.
- After the 3 minutes are up I will ask you to read your self-introductions.

Differential Equations & Dynamical Systems

What are differential equations?

An **ordinary differential equation** involves an unknown function $y(x)$ and its derivatives

$$y'(x) = \frac{dy}{dx}, \quad y''(x) = \frac{d^2y}{dx^2}, \quad \dots$$

Some examples are:

$$x^2y'' + xy' + (x^2 - 1)y = 0,$$

$$y''' + x(y')^2 = 0.$$

To solve a differential equation means to find all functions $y(x)$ that satisfy it.

Why differential equations?

- Differential equations appear everywhere in sciences, including **Physics**, **Economics**, **Biology**, and **Chemistry**.
- One of the most famous equations in Physics, Newton's second law of motion is a differential equation.
- Differential equations appear whenever we want to model a phenomenon where we know (or can reasonably guess) the rate of change of the quantities of interest.

- For example, in a problem about population growth we can make the assumption that the rate of increase P' of the population P is proportional to the size of the population, that is, $P' = kP$.
- This is a naive model that can be improved by modeling other aspects of population growth. However, all such models describe the problem by giving an expression for P'.
- This is because it is very common to be able to make reasonable assumptions about the rate of change of a quantity but not about the value of the quantity per se.

Dynamical Systems

- In our course dynamical systems will arise as solutions of systems of differential equations, that is, equations that involve one or more unknown functions depending on the same variable.

- The name "dynamical" comes from the fact that the unknown functions are typically functions of time and we want to understand how the solutions evolve in time.

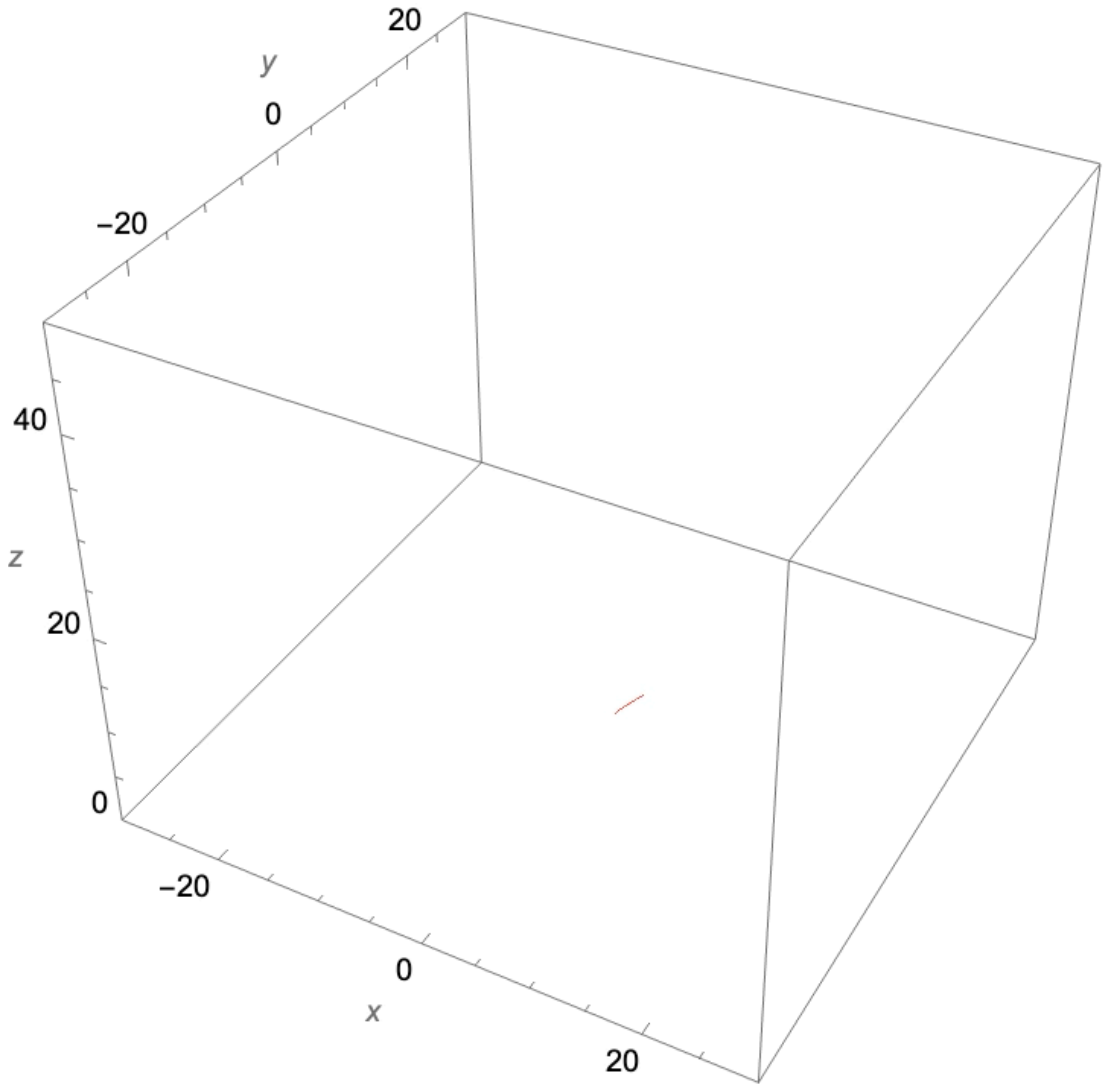
Lorenz system

A famous example of a dynamical system is the **Lorenz system**. It was developed by Edward Lorenz in 1963 as a simplified version of a weather model. The system is:

$$x' = \sigma(y - x)$$

$$y' = -xz + \rho x - y$$

$$z' = xy - bz$$



Signature Work

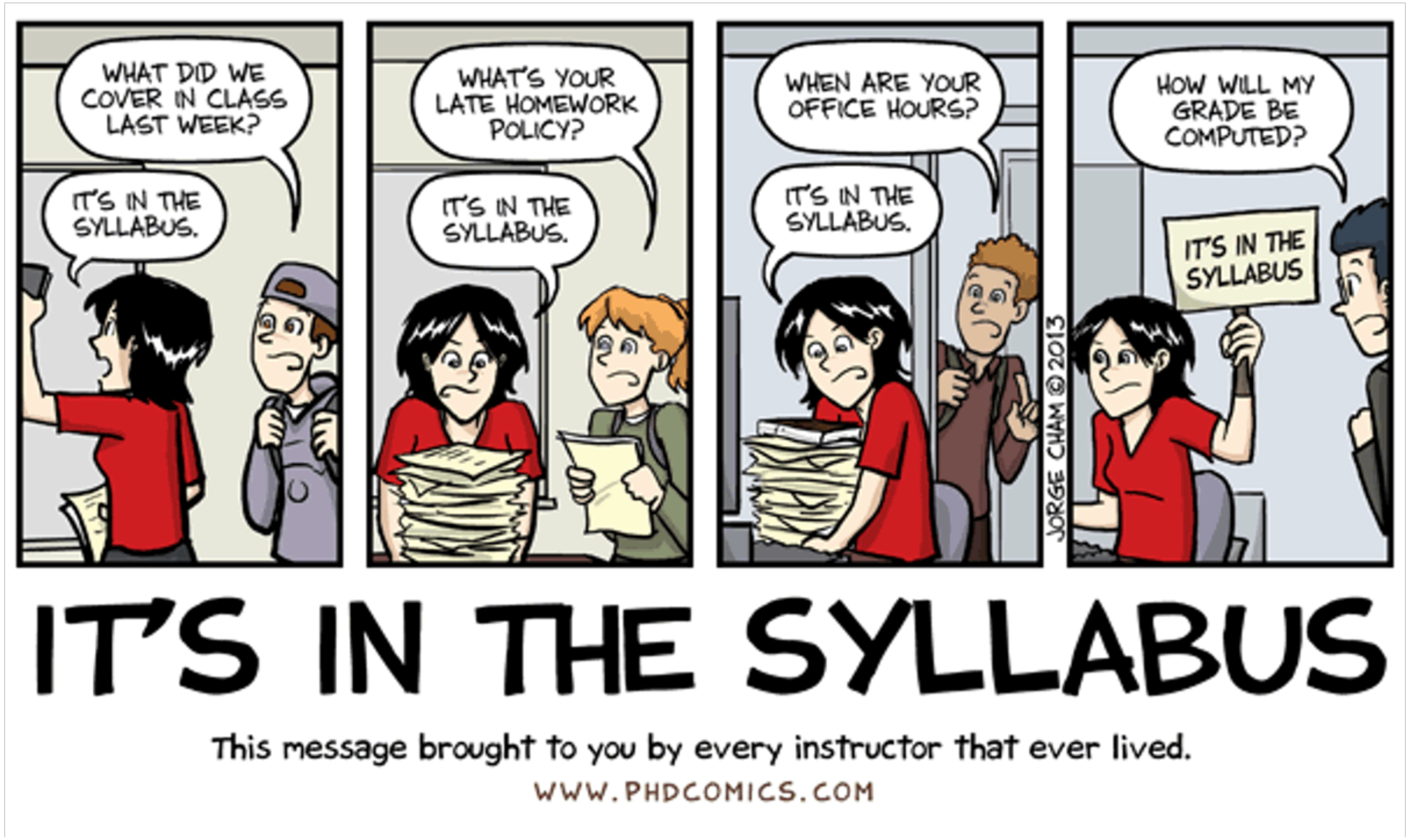
- MATH 303 can be the starting point for several Signature Work projects since Dynamical Systems appear everywhere.
- Some possible projects (list is far from exhaustive):
  - Machine learning of dynamics
  - Synchronization
  - Order and chaos

Syllabus

Syllabus

- The course syllabus is available through Teams.
- As we make progress through the course I will be updating the syllabus, also taking into account your feedback.
- If you find any mistakes, please let me know through e-mail or PM in Teams.

Syllabus


WHAT DID WE COVER IN CLASS LAST WEEK?
IT'S IN THE SYLLABUS.
WHAT'S YOUR LATE HOMEWORK POLICY?
IT'S IN THE SYLLABUS.
WHEN ARE YOUR OFFICE HOURS?
IT'S IN THE SYLLABUS.
HOW WILL MY GRADE BE COMPUTED?
IT'S IN THE SYLLABUS
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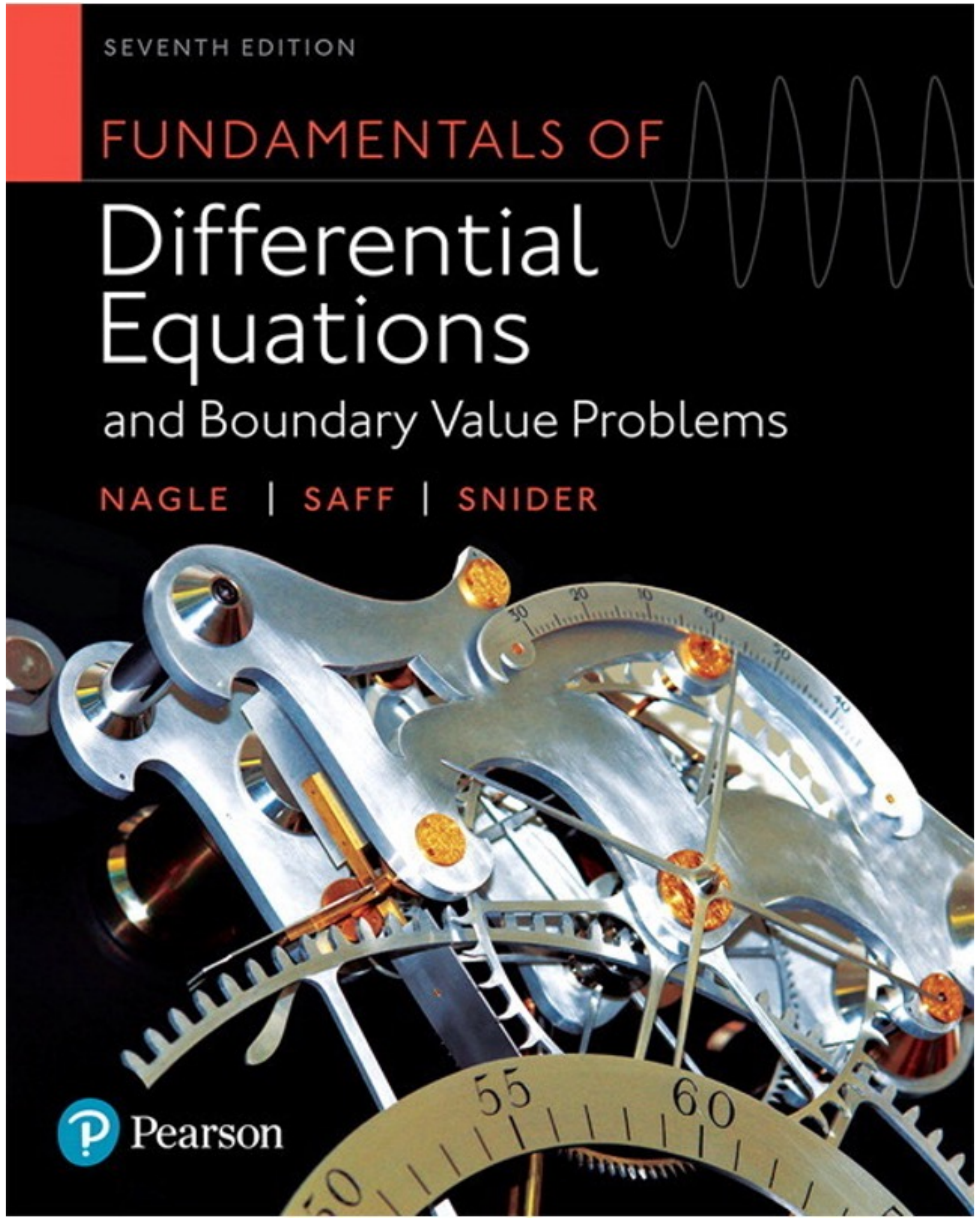
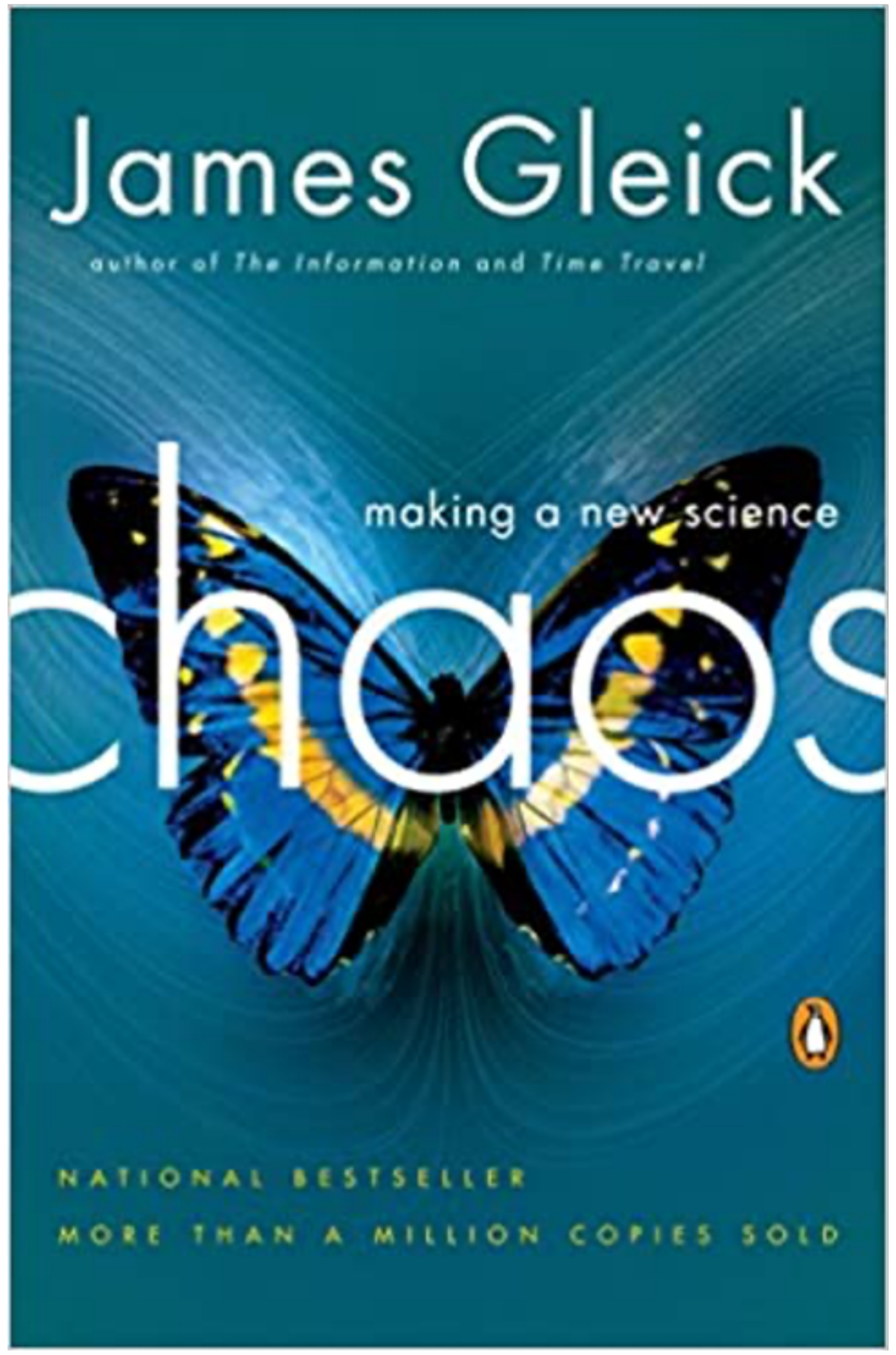
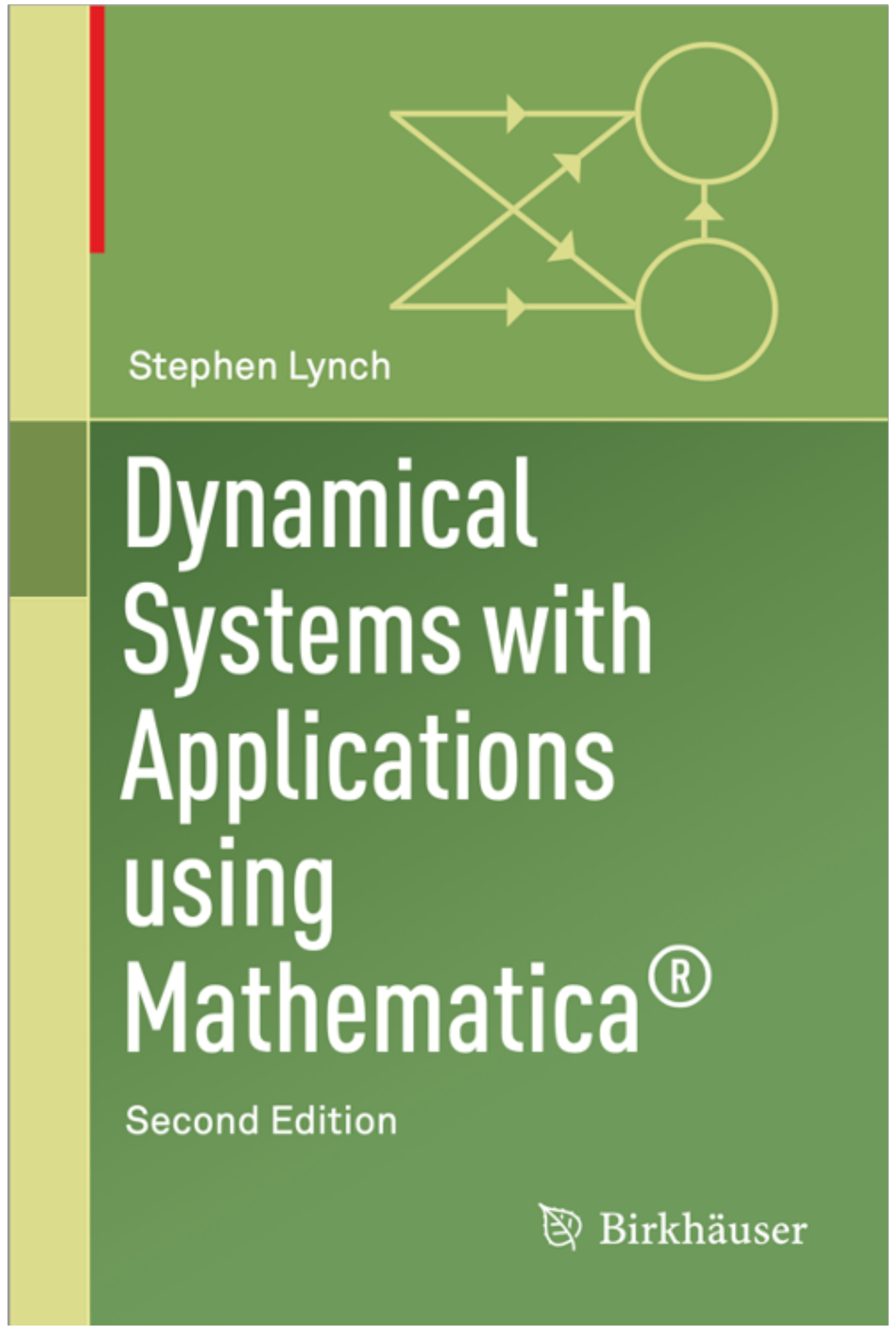
Textbook


SEVENTH EDITION
FUNDAMENTALS OF
Differential Equations
and Boundary Value Problems
NAGLE | SAFF | SNIDER
Pearson

Other resources





Other resources

Contact

- **Office:** IB 1020
- **Office hours:** TBD and on Zoom by appointment
- **E-mail address:** k.efstathiou@dukekunshan.edu.cn
- **Personal website:** https://www.efstathiou.gr/

Assessment

- **6 homework assignments** (25%)
- **2 midterm exams** (20%)
- **Final exam** (30%)
- **Applied project** (15% for the written report, 10% for the presentation)

Applied project

- I will provide a list of topics to choose from, but **you can also propose your own topics**.
- 3-4 groups, 2-3 students per group.
- Written report, maximum 10 pages, use Overleaf.
  - I will provide a LaTeX template for the report.
  - The report will be scaffolded throughout the session (see syllabus for dates).
- There is going to be a practice presentation that will be used only for feedback (not graded).

Poll

Which software will we be using for homework assignments and exams?

Respond at http://pollev.com/ke1

For tomorrow...

- Install **Mathematica** from https://software.duke.edu.
- Go through the Mathematica tutorials mentioned in the syllabus.
- Create a (free) **Overleaf** account at https://overleaf.com (this is not necessary for tomorrow but try to do it and let me know if you have any problems).
- Watch the 3Blue1Brown **Youtube video** at https://youtu.be/p_di4Zn4wz4 if you haven't watched it already.