Nonlinear Dynamical Systems

MATH X411: Topics in Applied Mathematics, B

(Semester 2, 2026)

Instructor: Sanjeeva Balasuriya
Office: Ingkarni Wardli 6.15 Email: sanjeeva.balasuriya@adelaide.edu.au
Forum: Mondays, 9.10 to 11.00am, Napier 144 Consultations: by appointment

Alert

We are in an era where 'typical' courses are becoming irrelevant – both in their applicability for the future, and the teaching/assessment mechanisms used. As Artificial Intelligence (AI) improves at a rapid pace, this course reimagines the learning process with regards to the course content, its usefulness, pedagogical methods, assessment tasks, and skills-development that may be more appropriate for a course adapting to not just the present, but the future.

Prerequisites

- From a typical first-year university curriculum: basic ideas on ordinary differential equations and linear algebra
- From typical second-year level courses: multivariable calculus, and either a numerical methods or differential equations course
- Ability to perform numerical calculations *with the aid of AI*, in any platform (such as Python, Matlab, Julia) on the student's personal laptop
- Willingness to take AI outputs and *dig both deeper and broader*
- Enthusiasm to actively participate in an unusual collaborative learning adventure in a rapidly changing environment

Attendance

Given the discovery-based learning structures employed, *attendance at all scheduled classes is mandatory.*

A Typical Class

... will consist of investigating—usually individually but in some instances as groupwork—the topic of the week. Such investigation will require consulting AI for information, tracking more detailed information sources, using AI to write codes, running numerics, and discussing difficulties and findings. Students must bring along a laptop to class, which must be equipped with access to the internet and the ability to run code (including obtaining plots) in the students' favourite platform (Python, Matlab or Julia are recommended for their mathematical capabilities). Students will be asked to share their work during class time, which will lead towards the 'participation' grade. The instructor will be helping and guiding the process throughout.

Weekly Reports

By the beginning of each class, students must submit a Weekly Report of their learnings/findings from the previous class. (A list of bullet points of the relevant material covered in class each week will be available.) The Weekly Report will be graded on the coarse five-point scale below, but the instructor will also provide written feedback. After this feedback, students are expected to continue editing their reports *throughout the semester*, to avoid overloading themselves at the end of the semester. Expanded/edited versions of these reports comprise the Course Dossier, which is a part of the Final Dossier.

Weekly Report grade	0	1	2	3	4	5
Meaning	not handed in	very weak	marginal	adequate	good	outstanding

Project

As the semester proceeds, students will choose a relevant topic—of theoretical, application-oriented, computational, or combined focus—for a small project. Its final deliverables include a Project Report (as a part of the Final Dossier) and a Project Presentation. More information on the Project (choosing topics, expectations, etc) will be provided in separate documentation in due course.

Project Presentation

Each student shall do a Project Presentation during the final class meeting of the semester. Innovative presentations are encouraged (subject to certain expectations on content that will be communicated).

Final Dossier

The Final Dossier is the replacement for a Final Examination for this course, and will be due by the Exam Period. More information will be provided in due course, but in broad terms, it will consist of two parts:

- *Course Dossier*: an edited and amplified collection of the Weekly Reports into a scientific presentation of the student's individual learnings from the course as a whole;
- *Project Report*: the final report on the project pursued during the last few weeks of the semester; and
- *AI Usage and Reflection*: a description/reflection of how you used AI to leverage your learning.

Planning Workload

This course requires sustained and disciplined outside-of-classtime work, and an important skill to develop is *planning* one's workload and taking responsibility for one's learning over the semester. For example, it is essential to keep up with working towards the Course Dossier throughout the semester. Developing such responsibility, time-management and planning is a broad skill essential for the future.

AI Should be Leveraged for Learning

- our philosophy for this course

Students are encouraged to use AI in their Weekly Reports, codes, Course Dossier, Project Report and in preparing their Project Presentation — essentially, in the entire course. *However*, all information within these should be demonstrably validated (e.g., scientifically-appropriate citations need to be checked and provided for all information, AI-generated code needs to be validated for test situations in which numbers are available in the scientific literature, etc). You will be asked to describe your usage, and your reflections on the process, as a part of your Final Dossier.

Assessment Weightings

*detailed expectations will be provided

Semester Portfolio	*50% total*	25%	Weekly Reports*
		15%	Participation
		10%	Presentation (instructor+peer score)*
Final Dossier	*50% total*	30%	Course Dossier*
		15%	Project Report*
		5%	AI Usage and Reflection*

Course Content (Tentative)

- some stated only as brief phrases to aid AI-discovery

Week 1	Bifurcations and chaos in discrete chaotic maps: cobweb plots, embedding (logistic map, standard map, Hénon attractor)
Week 2	Bifurcations and chaos in discrete maps (continued)
Week 3	Proof of chaos (Smale horseshoe map)
Week 4	Lyapunov exponents in ergodic differential equations (Lorenz '63, Lorenz '96)
Week 5	Extension week (no classes will be held – catch up time!)
Week 6	Coherent structures in nonautonomous flows: finite-time Lyapunov exponents (linear systems, double-gyre, Rössler)
Week 7	Coherent structures in nonautonomous flows: other methods (relationship to stable/unstable manifolds)
Week 8	Fractal dimensions of famous fractals (box-counting, information, correlation, Kaplan-Yorke)
Week 9	Extension week (no classes will be held – catch up time!)
Week 10	Data-driven and applied dynamical systems (ocean data, climate models)
Week 11	Noisy dynamical systems and uncertainty quantification
Week 12	Project presentations