
# UNSW SCIENCE

# School of Maths and Statistics

## Course outline

# MATH3201 / MATH5295

# Dynamical Systems and Chaos

## Term 3, 2022

Cricos Provider Code: 00098G

## Staff

| Position | Name | Email | Room |
|---|---|---|---|
| Lecturer-in-charge | Professor Gary Froyland | g.froyland@unsw.edu.au | RC:3060 |

Please refer to your Timetable on MyUNSW for your Lecture Tut, Lab enrolment days and times.

Timetable weblink:

MATH3201: https://timetable.unsw.edu.au/2022/MATH3201.html

MATH5295: https://timetable.unsw.edu.au/2022/MATH5295.html

## Administrative Contacts

Please visit the School of Mathematics and Statistics website for a range of information on School Policies, Forms and Help for Students.

For information on Courses, please go to “Student Life & resources page” and either Undergraduate Courses and/or Postgraduate Courses for information on all course offerings.

The “Student Notice Board” can be located by going to the “Student Life & resources” page; Notices are posted regularly for your information here. Please familiarise yourself with the information found in these locations. The School web page is: https://www.maths.unsw.edu.au

If you cannot find the answer to your queries on the web you are welcome to contact the Student Services Office directly.

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| By email | Undergraduate | ug.mathsstats@unsw.edu.au |
| | Postgraduate | pg.mathsstats@unsw.edu.au |
| By phone: | 9385 7053 | |

Should we need to contact you, we will use your official UNSW email address of in the first instance. **It is your responsibility to regularly check your university email account. Please state your student number in all emails.**

## Course Information

**Course:** 6 units of credit (UOC)

**Assumed knowledge / Pre-Requisite:** (MATH2501 or MATH2601 or MATH2089 or MATH2099) and (MATH2011 or MATH2111 or MATH2018 (DN) or MATH2019 (DN) or MATH2069 (CR) or MATH2121 or MATH2221).

We are aware some course exclusions on the Handbook may be different to the School website. We are in the process of updating this information. Meanwhile, students should be following the Handbook course information with the School website information as a supplement.

## Course Aims

Dynamical Systems is a subject that sits at the threshold of pure and applied mathematics and has links to many other areas of mathematics, including Analysis, Linear Algebra, Measure Theory, Ergodic Theory, Functional Analysis, Topology, Numerical Analysis, Stochastic Processes, Group Theory, and Mathematical Modelling. This course will make use of many mathematical concepts and tools that you have learnt so far, and refine those parts of mathematics that are particularly useful for studying dynamical systems.

## Course Description

Many nonlinear systems do not have explicit solutions. The dynamical systems approach shifts the focus from finding explicit solutions to discovering geometric properties of solutions. It also recognises that even a small amount of nonlinearity in a physical system can be responsible for very complicated chaotic behaviour. In this course you will learn the fundamentals of dynamical systems in discrete-time maps and continuous-time ODEs, allowing you to analyse the local and global behaviour of dynamical systems. You will also learn how to analyse time series data using nonlinear tools and build appropriate predictive models. Throughout the course, MATLAB will be used frequently for computations. The course is made up of three main topic areas:

*Nonlinear maps: The building blocks of dynamics:* fixed and periodic points, stable/unstable sets, transitivity, conjugacy, sensitive dependence on initial conditions, Lyapunov exponents, invariant measures, recurrence, hyperbolicity, stable manifolds, chaotic attractors, Smale's Horseshoe, Poincare recurrence.

*Nonlinear ODEs: A geometric, qualitative approach to ODEs:* phase portraits, equilibria, periodic and chaotic trajectories, sources, sinks, and saddles, local stable and unstable subspaces, local hyperbolicity, Poincare-Bendixson.

*Nonlinear time series analysis: What to do with real data?:* stationarity, linear or nonlinear, Takens embedding and delay reconstruction, conjugacy invariants, modelling and forecasting.

## Assessment and Deadlines

| Assessment | Due Week | Weighting % | Course Learning Outcome (CLO) |
|---|---|---|---|
| Small formative task prior to census date | 3 | 0% | CLO2,3,4 |
| Project in pairs, including individual responses | 6 | 20% | CLO1,2,3,4 |
| Project in pairs, including individual responses | 9 | 20% | CLO1,2,3,4 |
| Final Examination | Exam Period | 60% | CLO1,2,3,4 |

## Late Submission of Assessment Tasks

No late submissions will be accepted. (Where "late" in this context means after any extensions granted for Special Consideration or Equitable Learning Provisions.)

## Course Learning Outcomes (CLO)

- CLO1: Model dynamical phenomena and demonstrate an understanding of those phenomena at a deeper level than in previous courses
- CLO2: Demonstrate the utility of the mathematics learned prior to the course and show the connection between dynamical systems and those other mathematics subjects
- CLO3: Demonstrate development in problem solving skills as applied to dynamical systems
- CLO4 Display advanced competency in mathematical presentation

## Course Schedule

The course will include material taken from some of the following topics. This is should only serve as a guide as it is not an extensive list of the material to be covered and the timings are approximate. The course content is ultimately defined by the material covered in lectures.

| Weeks | Topic |
|---|---|
| 1 | *Discrete-time dynamics:* periodic points, stable/unstable sets, graphical analysis of maps, linearization around periodic orbits, derivative condition for stability of a periodic orbit, topological conjugacy. |
| 2 | *Discrete-time dynamics:* invariant sets, topological transitivity, sensitive dependence on initial conditions, chaos, Lyapunov exponents, measure-preserving transformations, Poincare Recurrence Theorem, ergodicity. |
| 3 | *Discrete-time dynamics:* linear maps in R^n, hyperbolicity, stable/unstable subspaces, linearization about fixed and periodic points in R^n, global dynamics of the Henon map, Hartman-Grobman Theorem. |
| 4 | *Discrete-time dynamics:* Stable Manifold Theorem, Inclination Lemma, chaotic attractors. *Continuous-time dynamics:* ODEs and flow maps. |
| 5 | *Continuous-time dynamics:* general form of solutions for linear flows, phase portraits and classification of linear flows, unstable/stable/centre subspaces, hyperbolic linear flows. |
| 7 | *Continuous-time dynamics:* linearization about hyperbolic fixed points, Hartman-Grobman Theorem for flows, stable/unstable manifolds of fixed points, global dynamics of the pendulum, periodic orbits, invariant sets. |
| 8 | *Continuous-time dynamics:* omega-limit sets, Poincare-Bendixson Theorem. Nonlinear time series analysis: observation function formalism, stationarity, linear autoregresive models. |
| 9 | *Nonlinear time series analysis*: Takens' Embedding Theorem. |

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|---|---|
| 10 | *Nonlinear time series analysis:* building a nonlinear model from time series, embedding dimension, false nearest neighbours, time delay embedding, entropy, mutual information. |

## Textbooks

There is no textbook. Some of the lecture material is based on *An Introduction to Chaotic Dynamical Systems*, by Robert L. Devaney; *Dynamical Systems: Stability, Symbolic Dynamics, and Chaos*, by Clark Robinson; *Nonlinear Time Series Analysis*, by Holger Kantz and Thomas Schreiber.

## Moodle

Log in to Moodle to find announcements, general information, notes, lecture slide, classroom tutorial and assessments etc. https://moodle.telt.unsw.edu.au

## School and UNSW Policies

The School of Mathematics and Statistics has adopted a number of policies relating to enrolment, attendance, assessment, plagiarism, cheating, special consideration etc. These are in addition to the Policies of The University of New South Wales. Individual courses may also adopt other policies in addition to or replacing some of the School ones. These will be clearly notified in the Course Initial Handout and on the Course Home Pages on the Maths Stats web site.

Students in courses run by the School of Mathematics and Statistics should be aware of the School and Course policies by reading the appropriate pages on the Maths Stats web site starting at:
https://www.maths.unsw.edu.au/currentstudents/assessment-policies

The School of Mathematics and Statistics will assume that all its students have read and understood the School policies on the above pages and any individual course policies on the Course Initial Handout and Course Home Page. Lack of knowledge about a policy will not be an excuse for failing to follow the procedure in it.

## Academic Integrity and Plagiarism

UNSW has an ongoing commitment to fostering a culture of learning informed by academic integrity. All UNSW staff and students have a responsibility to adhere to this principle of academic integrity. Plagiarism undermines academic integrity and is not tolerated at UNSW. *Plagiarism at UNSW is defined as using the words or ideas of others and passing them off as your own.*

The **UNSW Student Code** provides a framework for the standard of conduct expected of UNSW students with respect to their academic integrity and behaviour. It outlines the primary obligations of students and directs staff and students to the Code and related procedures.

In addition, it is important that students understand that it is not permissible to buy essay/writing services from third parties as the use of such services constitutes plagiarism because it involves

using the words or ideas of others and passing them off as your own. Nor is it permissible to sell copies of lecture or tutorial notes as students do not own the rights to this intellectual property.

If a student breaches the Student Code with respect to academic integrity, the University may take disciplinary action under the **Student Misconduct Procedure**.

The UNSW Student Code and the Student Misconduct Procedure can be found at: https://student.unsw.edu.au/plagiarism

An online Module "Working with Academic Integrity" (https://student.unsw.edu.au/aim) is a six-lesson interactive self-paced Moodle module exploring and explaining all of these terms and placing them into your learning context. It will be the best one-hour investment you've ever made.

## Plagiarism

Plagiarism is presenting another person's work or ideas as your own. Plagiarism is a serious breach of ethics at UNSW and is not taken lightly. So how do you avoid it? A one-minute video for an overview of how you can avoid plagiarism can be found https://student.unsw.edu.au/plagiarism.

## Additional Support

## ELISE (Enabling Library and Information Skills for Everyone)

ELISE is designed to introduce new students to studying at UNSW.

Completing the ELISE tutorial and quiz will enable you to:

- analyse topics, plan responses and organise research for academic writing and other assessment tasks
- effectively and efficiently find appropriate information sources and evaluate relevance to your needs
- use and manage information effectively to accomplish a specific purpose
- better manage your time
- understand your rights and responsibilities as a student at UNSW
- be aware of plagiarism, copyright, UNSW Student Code of Conduct and Acceptable Use of UNSW ICT Resources Policy
- be aware of the standards of behaviour expected of everyone in the UNSW community
- locate services and information about UNSW and UNSW Library

Some of these areas will be familiar to you, others will be new. Gaining a solid understanding of all the related aspects of ELISE will help you make the most of your studies at UNSW.

The *ELISE* training webpages: https://subjectguides.library.unsw.edu.au/elise/aboutelise

## Equitable Learning Services (ELS)

If you suffer from a chronic or ongoing illness that has, or is likely to, put you at a serious disadvantage, then you should contact the Equitable Learning Services (previously known as SEADU) who provide confidential support and advice.

They assist students:

- living with disabilities
- with long- or short-term health concerns and/or mental health issues
- who are primary carers
- from low SES backgrounds
- of diverse genders, sexes and sexualities
- from refugee and refugee-like backgrounds
- from rural and remote backgrounds
- who are the first in their family to undertake a bachelor-level degree.

Their web site is: https://student.unsw.edu.au/els/services

Equitable Learning Services (ELS) may determine that your condition requires special arrangements for assessment tasks. Once the School has been notified of these, we will make every effort to meet the arrangements specified by ELS.

Additionally, if you have suffered significant misadventure that affects your ability to complete the course, please contact your Lecturer-in-charge in the first instance.

## Academic Skills Support and the Learning Centre

The Learning Centre offers academic support programs to all students at UNSW Australia. We assist students to develop approaches to learning that will enable them to succeed in their academic study. For further information on these programs please go to:

http://www.lc.unsw.edu.au/services-programs

## Applications for Special Consideration for Missed Assessment

Please adhere to the Special Consideration Policy and Procedures provided on the web page below when applying for special consideration. https://student.unsw.edu.au/special-consideration

Please note that the application is not considered by the Course Authority, it is considered by a centralised team of staff at the Nucleus Student Hub.

The School will contact you (via student email account) after special consideration has been granted to reschedule your missed assessment, for a *lab test or paper-based test* only.

For applications for special consideration for *assignment extensions*, please note that the new submission date and/or outcome will be communicated through the special consideration web site only, no communication will be received from the School.

For Dates on Final Term Exams and Supplementary Exams please check the “Key Dates for Exams” ahead of time to avoid booking holidays or work obligations.

https://student.unsw.edu.au/exam-dates

If you believe your application for Special Consideration has not been processed, you should email specialconsideration@unsw.edu.au immediately for advice.

## Course Evaluation and Development (MyExperience)

Student feedback is very important to continual course improvement. This is demonstrated within the School of Mathematics and Statistics by the implementation of the UNSW online student survey *myExperience*, which allows students to evaluate their learning experiences in an anonymous way. *myExperience* survey reports are produced for each survey. They are released to staff after all student assessment results are finalised and released to students. Course convenor will use the feedback to make ongoing improvements to the course.