



# MATH332

## Nonlinear Dynamics and Chaos

S2 Day 2018

*Dept of Mathematics*

### Contents

<u>General Information</u>	2
<u>Learning Outcomes</u>	3
<u>General Assessment Information</u>	3
<u>Assessment Tasks</u>	4
<u>Delivery and Resources</u>	7
<u>Policies and Procedures</u>	7
<u>Graduate Capabilities</u>	8
<u>Changes since First Published</u>	15

#### **Disclaimer**

Macquarie University has taken all reasonable measures to ensure the information in this publication is accurate and up-to-date. However, the information may change or become out-dated as a result of change in University policies, procedures or rules. The University reserves the right to make changes to any information in this publication without notice. Users of this publication are advised to check the website version of this publication [or the relevant faculty or department] before acting on any information in this publication.

## General Information

Unit convenor and teaching staff

Lecturer

Jim Denier

[jim.denier@mq.edu.au](mailto:jim.denier@mq.edu.au)

Contact via 9850 8956

12 Wally's Walk (E7A) 6.03

by appointment

Lecturer/Convenor

Paul Smith

[paul.smith@mq.edu.au](mailto:paul.smith@mq.edu.au)

Contact via 9850 8944

12 Wally's Walk (E7A) 7.26

Tuesday, 2-3pm

Jim Denier

[jim.denier@mq.edu.au](mailto:jim.denier@mq.edu.au)

Credit points

3

Prerequisites

MATH235 and (MATH232 or MATH236)

Corequisites

Co-badged status

Unit description

The remarkable fact that determinism does not guarantee regular or predictable behaviour is having a major impact on many fields of science and engineering, as well as mathematics.

The discovery of chaos, or of chaotic motions, in simple dynamical systems changes our understanding of the foundations of physics and has many practical applications as well, shedding new light on the workings of lasers, fluids, mechanical structures and chemical reactions. Dynamical systems involve the study of maps and systems of differential equations. In this unit, the diversity of nonlinear phenomena is explored through the study of second-order differential equations, and one-dimensional and two-dimensional maps. Chaotic motions are introduced by a study of the driven pendulum, a second-order system that includes nonlinear aspects usually ignored in simpler treatments. An appropriate balance between forcing and damping leads to irregular, but bounded, motions that do not repeat themselves, even approximately – truly chaotic motion in a simple deterministic system.

## Important Academic Dates

Information about important academic dates including deadlines for withdrawing from units are available at <https://www.mq.edu.au/study/calendar-of-dates>

## Learning Outcomes

On successful completion of this unit, you will be able to:

Knowledge of the principles and basic concepts in a theory of Nonlinear Dynamical Systems, both of discrete systems and continuous ones through Differential Equations.

In particular, gain an appreciation of the characteristics of 'chaotic' behaviour.

Gain the ability to use modern computing software to model a range of phenomena in science and engineering, displaying the complexity that can occur with nonlinear systems.

Understanding of the breadth of the theory of Nonlinear Systems, and how the distinction between periodic and non-periodic orbits is related to the very numbers used to model or describe the state of a system.

Ability to construct logical, clearly presented and justified mathematical arguments incorporating deductive reasoning especially in the context of the Dynamical Systems, and to produce appropriate computer graphics to aptly illustrate the phenomena involved.

Preparation for further studies in the areas of Dynamical Systems and Differential Equations.

## General Assessment Information

Late submission of assessment tasks, without an extension (arranged *prior* to the due date) or without an appropriate Disruption to Studies, will result in a zero being awarded for that assessment task. Additionally, assessment tasks handed in without a signed coversheet will also result in a zero for that task.

Information about the submission process of assessment tasks will be made available on iLearn.

**HURDLES:** This unit has no hurdle requirements. This means that there are no second chance examinations and assessments if you happen to fail at your first attempt, and your final grade is determined by adding the marks obtained for your examinations and assessments. Students should aim to get at least 60% for the course work in order to be reasonably confident of passing the unit.

**IMPORTANT:** If you apply for Disruption to Study for your final examination, you must make yourself available for the week of December 10 – 14, 2018. If you are not available at that time, there is no guarantee an additional examination time will be offered. Specific examination dates

and times will be determined at a later date.

## Assessment Tasks

Name	Weighting	Hurdle	Due
<a href="#">Final Examination</a>	60%	No	Exam session
<a href="#">Assignment 1</a>	11%	No	See iLearn
<a href="#">Assignment 2</a>	11%	No	See iLearn
<a href="#">Assignment 3</a>	11%	No	See iLearn
<a href="#">Project</a>	7%	No	Week 2

### Final Examination

Due: **Exam session**

Weighting: **60%**

Final Exam, covering content from the whole teaching Session.

On successful completion you will be able to:

- Knowledge of the principles and basic concepts in a theory of Nonlinear Dynamical Systems, both of discrete systems and continuous ones through Differential Equations. In particular, gain an appreciation of the characteristics of 'chaotic' behaviour.
- Understanding of the breadth of the theory of Nonlinear Systems, and how the distinction between periodic and non-periodic orbits is related to the very numbers used to model or describe the state of a system.
- Ability to construct logical, clearly presented and justified mathematical arguments incorporating deductive reasoning especially in the context of the Dynamical Systems, and to produce appropriate computer graphics to aptly illustrate the phenomena involved.
- Preparation for further studies in the areas of Dynamical Systems and Differential Equations.

### Assignment 1

Due: **See iLearn**

Weighting: **11%**

Assignment based upon ideas and techniques from the lectures in Weeks 1–4. Some computational techniques may be required also.

On successful completion you will be able to:

- Knowledge of the principles and basic concepts in a theory of Nonlinear Dynamical Systems, both of discrete systems and continuous ones through Differential Equations. In particular, gain an appreciation of the characteristics of 'chaotic' behaviour.
- Gain the ability to use modern computing software to model a range of phenomena in science and engineering, displaying the complexity that can occur with nonlinear systems.
- Understanding of the breadth of the theory of Nonlinear Systems, and how the distinction between periodic and non-periodic orbits is related to the very numbers used to model or describe the state of a system.
- Ability to construct logical, clearly presented and justified mathematical arguments incorporating deductive reasoning especially in the context of the Dynamical Systems, and to produce appropriate computer graphics to aptly illustrate the phenomena involved.
- Preparation for further studies in the areas of Dynamical Systems and Differential Equations.

## Assignment 2

Due: **See iLearn**

Weighting: **11%**

Assignment based upon ideas and techniques from the lectures in Weeks 5–7. Some computational techniques will be required.

On successful completion you will be able to:

- Knowledge of the principles and basic concepts in a theory of Nonlinear Dynamical Systems, both of discrete systems and continuous ones through Differential Equations. In particular, gain an appreciation of the characteristics of 'chaotic' behaviour.
- Gain the ability to use modern computing software to model a range of phenomena in science and engineering, displaying the complexity that can occur with nonlinear systems.
- Understanding of the breadth of the theory of Nonlinear Systems, and how the distinction between periodic and non-periodic orbits is related to the very numbers used to model or describe the state of a system.
- Ability to construct logical, clearly presented and justified mathematical arguments incorporating deductive reasoning especially in the context of the Dynamical Systems, and to produce appropriate computer graphics to aptly illustrate the phenomena

involved.

- Preparation for further studies in the areas of Dynamical Systems and Differential Equations.

## Assignment 3

Due: **See iLearn**

Weighting: **11%**

Assignment based upon ideas and techniques from the lectures in Weeks 8–10. Some computational techniques may be required also.

On successful completion you will be able to:

- Knowledge of the principles and basic concepts in a theory of Nonlinear Dynamical Systems, both of discrete systems and continuous ones through Differential Equations. In particular, gain an appreciation of the characteristics of ‘chaotic’ behaviour.
- Understanding of the breadth of the theory of Nonlinear Systems, and how the distinction between periodic and non-periodic orbits is related to the very numbers used to model or describe the state of a system.
- Ability to construct logical, clearly presented and justified mathematical arguments incorporating deductive reasoning especially in the context of the Dynamical Systems, and to produce appropriate computer graphics to aptly illustrate the phenomena involved.
- Preparation for further studies in the areas of Dynamical Systems and Differential Equations.

## Project

Due: **Week 2**

Weighting: **7%**

Project, to be worked on and completed in Week 2, is to reinforce core ideas of linear algebra with techniques from numerical linear algebra and MATLAB and are requisite for the Continuous Dynamical Systems stream of this unit.

On successful completion you will be able to:

- Knowledge of the principles and basic concepts in a theory of Nonlinear Dynamical Systems, both of discrete systems and continuous ones through Differential Equations. In particular, gain an appreciation of the characteristics of ‘chaotic’ behaviour.
- Ability to construct logical, clearly presented and justified mathematical arguments incorporating deductive reasoning especially in the context of the Dynamical Systems,

and to produce appropriate computer graphics to aptly illustrate the phenomena involved.

- Preparation for further studies in the areas of Dynamical Systems and Differential Equations.

## Delivery and Resources

- 4 hours of face-to-face time per week, in 2 blocks of 2 hours each.
- Weeks 1–6 are lectures/tutorials in Continuous Dynamical Systems.
- Weeks 7–12 are lectures/tutorials in Discrete Dynamical Systems.
- Week 13 is reserved for revision lectures for both Continuous & Discrete Dynamical Systems.

## Required and Recommended Texts and/or Materials

The following text is strongly recommended for the discrete dynamical systems material in this unit; it is available from the CO-OP Bookshop on campus, and is in the reference section of the Library.

- R.A. Holmgren, *A First Course in Discrete Dynamical Systems*, Springer

## Policies and Procedures

Macquarie University policies and procedures are accessible from [Policy Central](https://staff.mq.edu.au/work/strategy-planning-and-governance/university-policies-and-procedures/policy-central) (<https://staff.mq.edu.au/work/strategy-planning-and-governance/university-policies-and-procedures/policy-central>). Students should be aware of the following policies in particular with regard to Learning and Teaching:

- [Academic Appeals Policy](#)
- [Academic Integrity Policy](#)
- [Academic Progression Policy](#)
- [Assessment Policy](#)
- [Fitness to Practice Procedure](#)
- [Grade Appeal Policy](#)
- [Complaint Management Procedure for Students and Members of the Public](#)
- [Special Consideration Policy](#) (**Note:** *The Special Consideration Policy is effective from 4 December 2017 and replaces the Disruption to Studies Policy.*)

Undergraduate students seeking more policy resources can visit the [Student Policy Gateway](https://students.mq.edu.au/support/study/student-policy-gateway) (<https://students.mq.edu.au/support/study/student-policy-gateway>). It is your one-stop-shop for the key policies you need to know about throughout your undergraduate student journey.

If you would like to see all the policies relevant to Learning and Teaching visit [Policy Central](https://staff.mq.edu.au/work/strategy-planning-and-governance/university-policies-and-procedures/p) (<https://staff.mq.edu.au/work/strategy-planning-and-governance/university-policies-and-procedures/p>

olicy-central).

## Student Code of Conduct

Macquarie University students have a responsibility to be familiar with the Student Code of Conduct: <https://students.mq.edu.au/study/getting-started/student-conduct>

## Results

Results shown in *iLearn*, or released directly by your Unit Convenor, are not confirmed as they are subject to final approval by the University. Once approved, final results will be sent to your student email address and will be made available in [eStudent](#). For more information visit <ask.mq.edu.au>.

## Student Support

Macquarie University provides a range of support services for students. For details, visit <http://students.mq.edu.au/support/>

## Learning Skills

Learning Skills (<mq.edu.au/learningskills>) provides academic writing resources and study strategies to improve your marks and take control of your study.

- [Workshops](#)
- [StudyWise](#)
- [Academic Integrity Module for Students](#)
- [Ask a Learning Adviser](#)

## Student Services and Support

Students with a disability are encouraged to contact the [Disability Service](#) who can provide appropriate help with any issues that arise during their studies.

## Student Enquiries

For all student enquiries, visit Student Connect at <ask.mq.edu.au>

## IT Help

For help with University computer systems and technology, visit [http://www.mq.edu.au/about\\_us/offices\\_and\\_units/information\\_technology/help/](http://www.mq.edu.au/about_us/offices_and_units/information_technology/help/).

When using the University's IT, you must adhere to the [Acceptable Use of IT Resources Policy](#). The policy applies to all who connect to the MQ network including students.

## Graduate Capabilities

### Creative and Innovative

Our graduates will also be capable of creative thinking and of creating knowledge. They will be imaginative and open to experience and capable of innovation at work and in the community. We



want them to be engaged in applying their critical, creative thinking.

This graduate capability is supported by:

## **Learning outcomes**

- Knowledge of the principles and basic concepts in a theory of Nonlinear Dynamical Systems, both of discrete systems and continuous ones through Differential Equations. In particular, gain an appreciation of the characteristics of 'chaotic' behaviour.
- Gain the ability to use modern computing software to model a range of phenomena in science and engineering, displaying the complexity that can occur with nonlinear systems.
- Understanding of the breadth of the theory of Nonlinear Systems, and how the distinction between periodic and non-periodic orbits is related to the very numbers used to model or describe the state of a system.
- Ability to construct logical, clearly presented and justified mathematical arguments incorporating deductive reasoning especially in the context of the Dynamical Systems, and to produce appropriate computer graphics to aptly illustrate the phenomena involved.
- Preparation for further studies in the areas of Dynamical Systems and Differential Equations.

## **Assessment tasks**

- Final Examination
- Assignment 1
- Assignment 2
- Assignment 3
- Project

## **Capable of Professional and Personal Judgement and Initiative**

We want our graduates to have emotional intelligence and sound interpersonal skills and to demonstrate discernment and common sense in their professional and personal judgement. They will exercise initiative as needed. They will be capable of risk assessment, and be able to handle ambiguity and complexity, enabling them to be adaptable in diverse and changing environments.

This graduate capability is supported by:

## **Learning outcomes**

- Knowledge of the principles and basic concepts in a theory of Nonlinear Dynamical Systems, both of discrete systems and continuous ones through Differential Equations.

In particular, gain an appreciation of the characteristics of 'chaotic' behaviour.

- Gain the ability to use modern computing software to model a range of phenomena in science and engineering, displaying the complexity that can occur with nonlinear systems.
- Understanding of the breadth of the theory of Nonlinear Systems, and how the distinction between periodic and non-periodic orbits is related to the very numbers used to model or describe the state of a system.
- Ability to construct logical, clearly presented and justified mathematical arguments incorporating deductive reasoning especially in the context of the Dynamical Systems, and to produce appropriate computer graphics to aptly illustrate the phenomena involved.
- Preparation for further studies in the areas of Dynamical Systems and Differential Equations.

## **Assessment tasks**

- Final Examination
- Assignment 1
- Assignment 2
- Assignment 3
- Project

## **Commitment to Continuous Learning**

Our graduates will have enquiring minds and a literate curiosity which will lead them to pursue knowledge for its own sake. They will continue to pursue learning in their careers and as they participate in the world. They will be capable of reflecting on their experiences and relationships with others and the environment, learning from them, and growing - personally, professionally and socially.

This graduate capability is supported by:

## **Learning outcomes**

- Knowledge of the principles and basic concepts in a theory of Nonlinear Dynamical Systems, both of discrete systems and continuous ones through Differential Equations. In particular, gain an appreciation of the characteristics of 'chaotic' behaviour.
- Gain the ability to use modern computing software to model a range of phenomena in science and engineering, displaying the complexity that can occur with nonlinear systems.
- Understanding of the breadth of the theory of Nonlinear Systems, and how the distinction between periodic and non-periodic orbits is related to the very numbers used to model or

describe the state of a system.

- Preparation for further studies in the areas of Dynamical Systems and Differential Equations.

## **Assessment tasks**

- Final Examination
- Assignment 1
- Assignment 2
- Assignment 3
- Project

## **Discipline Specific Knowledge and Skills**

Our graduates will take with them the intellectual development, depth and breadth of knowledge, scholarly understanding, and specific subject content in their chosen fields to make them competent and confident in their subject or profession. They will be able to demonstrate, where relevant, professional technical competence and meet professional standards. They will be able to articulate the structure of knowledge of their discipline, be able to adapt discipline-specific knowledge to novel situations, and be able to contribute from their discipline to inter-disciplinary solutions to problems.

This graduate capability is supported by:

## **Learning outcomes**

- Knowledge of the principles and basic concepts in a theory of Nonlinear Dynamical Systems, both of discrete systems and continuous ones through Differential Equations. In particular, gain an appreciation of the characteristics of 'chaotic' behaviour.
- Gain the ability to use modern computing software to model a range of phenomena in science and engineering, displaying the complexity that can occur with nonlinear systems.
- Understanding of the breadth of the theory of Nonlinear Systems, and how the distinction between periodic and non-periodic orbits is related to the very numbers used to model or describe the state of a system.
- Ability to construct logical, clearly presented and justified mathematical arguments incorporating deductive reasoning especially in the context of the Dynamical Systems, and to produce appropriate computer graphics to aptly illustrate the phenomena involved.
- Preparation for further studies in the areas of Dynamical Systems and Differential Equations.

## Assessment tasks

- Final Examination
- Assignment 1
- Assignment 2
- Assignment 3
- Project

## Critical, Analytical and Integrative Thinking

We want our graduates to be capable of reasoning, questioning and analysing, and to integrate and synthesise learning and knowledge from a range of sources and environments; to be able to critique constraints, assumptions and limitations; to be able to think independently and systemically in relation to scholarly activity, in the workplace, and in the world. We want them to have a level of scientific and information technology literacy.

This graduate capability is supported by:

## Learning outcomes

- Knowledge of the principles and basic concepts in a theory of Nonlinear Dynamical Systems, both of discrete systems and continuous ones through Differential Equations. In particular, gain an appreciation of the characteristics of 'chaotic' behaviour.
- Understanding of the breadth of the theory of Nonlinear Systems, and how the distinction between periodic and non-periodic orbits is related to the very numbers used to model or describe the state of a system.
- Ability to construct logical, clearly presented and justified mathematical arguments incorporating deductive reasoning especially in the context of the Dynamical Systems, and to produce appropriate computer graphics to aptly illustrate the phenomena involved.
- Preparation for further studies in the areas of Dynamical Systems and Differential Equations.

## Assessment tasks

- Final Examination
- Assignment 1
- Assignment 2
- Assignment 3
- Project

## Problem Solving and Research Capability

Our graduates should be capable of researching; of analysing, and interpreting and assessing data and information in various forms; of drawing connections across fields of knowledge; and they should be able to relate their knowledge to complex situations at work or in the world, in order to diagnose and solve problems. We want them to have the confidence to take the initiative in doing so, within an awareness of their own limitations.

This graduate capability is supported by:

### Learning outcomes

- Knowledge of the principles and basic concepts in a theory of Nonlinear Dynamical Systems, both of discrete systems and continuous ones through Differential Equations. In particular, gain an appreciation of the characteristics of 'chaotic' behaviour.
- Gain the ability to use modern computing software to model a range of phenomena in science and engineering, displaying the complexity that can occur with nonlinear systems.
- Understanding of the breadth of the theory of Nonlinear Systems, and how the distinction between periodic and non-periodic orbits is related to the very numbers used to model or describe the state of a system.
- Ability to construct logical, clearly presented and justified mathematical arguments incorporating deductive reasoning especially in the context of the Dynamical Systems, and to produce appropriate computer graphics to aptly illustrate the phenomena involved.
- Preparation for further studies in the areas of Dynamical Systems and Differential Equations.

### Assessment tasks

- Final Examination
- Assignment 1
- Assignment 2
- Assignment 3
- Project

## Effective Communication

We want to develop in our students the ability to communicate and convey their views in forms effective with different audiences. We want our graduates to take with them the capability to read, listen, question, gather and evaluate information resources in a variety of formats, assess, write clearly, speak effectively, and to use visual communication and communication technologies as appropriate.

This graduate capability is supported by:

## **Learning outcomes**

- Gain the ability to use modern computing software to model a range of phenomena in science and engineering, displaying the complexity that can occur with nonlinear systems.
- Ability to construct logical, clearly presented and justified mathematical arguments incorporating deductive reasoning especially in the context of the Dynamical Systems, and to produce appropriate computer graphics to aptly illustrate the phenomena involved.
- Preparation for further studies in the areas of Dynamical Systems and Differential Equations.

## **Assessment tasks**

- Final Examination
- Assignment 1
- Assignment 2
- Assignment 3
- Project

## **Engaged and Ethical Local and Global citizens**

As local citizens our graduates will be aware of indigenous perspectives and of the nation's historical context. They will be engaged with the challenges of contemporary society and with knowledge and ideas. We want our graduates to have respect for diversity, to be open-minded, sensitive to others and inclusive, and to be open to other cultures and perspectives: they should have a level of cultural literacy. Our graduates should be aware of disadvantage and social justice, and be willing to participate to help create a wiser and better society.

This graduate capability is supported by:

## **Learning outcomes**

- Understanding of the breadth of the theory of Nonlinear Systems, and how the distinction between periodic and non-periodic orbits is related to the very numbers used to model or describe the state of a system.
- Preparation for further studies in the areas of Dynamical Systems and Differential Equations.

## **Assessment tasks**

- Final Examination
- Assignment 1

- Assignment 2
- Assignment 3
- Project

## Socially and Environmentally Active and Responsible

We want our graduates to be aware of and have respect for self and others; to be able to work with others as a leader and a team player; to have a sense of connectedness with others and country; and to have a sense of mutual obligation. Our graduates should be informed and active participants in moving society towards sustainability.

This graduate capability is supported by:

### Learning outcome

- Preparation for further studies in the areas of Dynamical Systems and Differential Equations.

### Assessment tasks

- Final Examination
- Assignment 1
- Assignment 2
- Assignment 3
- Project

## Changes since First Published

Date	Description
13/07/2018	Changes to the timing of assessment tasks. Changes to the timing of delivery.