MATH332

Nonlinear Dynamics and Chaos

S2 Day 2017

Dept of Mathematics

Contents

General Information

Unit convenor and teaching staff
Lecturer/Convenor
Sophie Calabretto
sophie.calabretto@mq.edu.au
Contact via 9850 8950
12 Wally's Walk (E7A) 7.05
Thursday, 10-11am

Lecturer
Paul Smith
paul.smith@mq.edu.au
Contact via 9850 8944
12 Wally's Walk (E7A) 7.26
Monday, 12-1pm

Paul Smith
paul.smith@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 make 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 11 – 15, 2017. 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
Final Examination	60%	No	Exam session
Assignment 1	11%	No	See iLearn
Assignment 2	11%	No	See iLearn
Assignment 3	11%	No	See iLearn
Project	7%	No	Week 7

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 1–3. 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 5–6. 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 8–11. 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 7**
Weighting: **7%**

Project, to be worked on and completed in Week 7, is to reinforce core ideas and techniques in linear algebra, which 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 1–3 and 5–6 are lectures/tutorials in Discrete Dynamical Systems.
- Weeks 4 and 8–12 are lectures/tutorials in Continuous Dynamical Systems.
- Week 7 will not involve lectures/tutorials and is reserved for the independent completion of the Project.
- Week 13 is reserved for revision lectures for both Discrete & Continuous Dynamical Systems.

Policies and Procedures

Macquarie University policies and procedures are accessible from Policy Central. Students should be aware of the following policies in particular with regard to Learning and Teaching:

Academic Honesty Policy http://mq.edu.au/policy/docs/academic_honesty/policy.html

Assessment Policy http://mq.edu.au/policy/docs/assessment/policy_2016.html

Grade Appeal Policy http://mq.edu.au/policy/docs/gradeappeal/policy.html

Complaint Management Procedure for Students and Members of the Public http://www.mq.edu.au/policy/docs/complaint_management/procedure.html

Disruption to Studies Policy (in effect until Dec 4th, 2017): http://www.mq.edu.au/policy/docs/disruption_studies/policy.html

Special Consideration Policy (in effect from Dec 4th, 2017): https://staff.mq.edu.au/work/strategy-planning-and-governance/university-policies-and-procedures/policies/special-consideration

In addition, a number of other policies can be found in the Learning and Teaching Category of Policy 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/support/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/.

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