MATH332

Nonlinear Dynamics and Chaos

S2 Day 2019

Dept of Mathematics and Statistics

Contents

General Information

Unit convenor and teaching staff
Convenor/Lecturer
Sophie Calabretto
sophie.calabretto@mq.edu.au
Contact via 9850 8950
12 Wally's Walk, 6.25
Tuesday, 9-10am

Lecturer
Jim Denier
jim.denier@mq.edu.au
Contact via 9850 8956
12 Wally's Walk, 6.03
by appointment

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

HURDLES: This unit has a hurdle requirement. To satisfy the hurdle requirement you must score at least 50% on the final exam. Your final grade is determined by adding the marks obtained for your examinations and assignments.

ASSIGNMENT SUBMISSION: Assignment submission will be online through the iLearn page.

Submit assignments online via the appropriate assignment link on the iLearn page. A personalised cover sheet is not required with online submissions. Read the submission statement carefully before accepting it as there are substantial penalties for making a false declaration.

- Assignment submission is via iLearn. You should upload this as a single scanned PDF file.
- Please note the quick guide on how to upload your assignments provided on the iLearn page.
- Please make sure that each page in your uploaded assignment corresponds to only one A4 page (do not upload an A3 page worth of content as an A4 page in landscape). If you are using an app like Clear Scanner, please make sure that the photos you are using are clear and

shadow-free.

- It is your responsibility to make sure your assignment submission is legible.
- If there are technical obstructions to your submitting online, please email us to let us know.

You may submit as often as required prior to the due date/time. Please note that each submission will completely replace any previous submissions. It is in your interests to make frequent submissions of your partially completed work as insurance against technical or other problems near the submission deadline.

LATE SUBMISSION OF WORK: All assignments or assessments must be submitted by the official due date and time. No marks will be given to late work unless an extension has been granted following a successful application for Special Consideration. Please contact the unit convenor for advice as soon as you become aware that you may have difficulty meeting any of the assignment deadlines. It is in your interests to make frequent submissions of your partially completed work. Note that later submissions completely replace any earlier submission, and so only the final submission made before the due date will be marked.

FINAL EXAM POLICY: examinations for individuals or groups of students. All students are expected to ensure that they are available until the end of the teaching semester, that is, the final day of the official examination period. The only excuse for not sitting an examination at the designated time is because of documented illness or unavoidable disruption. In these special circumstances, you may apply for special consideration via ask.mq.edu.au.

SUPPLEMENTARY EXAMINATIONS:

IMPORTANT: If you receive special consideration for the final exam, a supplementary exam will be scheduled in the interval between the regular exam period and the start of the next session. If you apply for special consideration, you must give the supplementary examination priority over any other pre-existing commitments, as such commitments will not usually be considered an acceptable basis for a second application for special consideration. Please ensure you are familiar with the policy prior to submitting an application. You can check the supplementary exam information page on FSE101 in iLearn (https://bit.ly/FSESupp) for dates, and approved applicants will receive an individual notification sometime in the week prior to the exam with the exact date and time of their supplementary examination.

Assessment Tasks

Name	Weighting	Hurdle	Due
Assignment 1	15%	No	Week 4
Assignment 2	15%	No	Week 7
Assignment 3	10%	No	Week 11
Final Examination	60%	Yes	Final Examination Period

Assignment 1

Due: **Week 4**
Weighting: **15%**

Assignment 1

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: **Week 7**
Weighting: **15%**

Assignment 2

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: **Week 11**
Weighting: **10%**

Assignment 3

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.

Final Examination

Due: **Final Examination Period**
Weighting: **60%**
This is a hurdle assessment task (see assessment policy for more information on hurdle assessment tasks)

Final Exam

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.

Delivery and Resources

There will be three formal contact hours per week, consisting of three lectures.

Required and Recommended Texts and/or Materials

Although there is not a single textbook that will cover the unit, some suggested resources will be detailed on iLearn.

Unit Schedule

Weeks 1-8: Continuous Dynamical Systems

Weeks 9-12: Applications of Continuous Dynamical Systems

Week 13: Revision (no lectures)

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). 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). 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/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/study/getting-started/student-conduct

Results

Results published on platform other than eStudent, (eg. iLearn, Coursera etc.) 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 or if you are a Global MBA student contact globalmba.support@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

If you are a Global MBA student contact globalmba.support@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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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