MATH3902

Nonlinear Dynamics and Chaos

Session 1, In person-scheduled-weekday, North Ryde 2023

School of Mathematical and Physical Sciences

Contents

General Information

Unit convenor and teaching staff
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Credit points
10

Prerequisites
(MATH2010 or MATH235) and (MATH2020 or MATH2110 or 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 changed our understanding of the foundations of physics and has found many practical applications. 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 second-order systems, in which nonlinearity is usually ignored in simpler treatments.

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:

ULO1: Explain the principles and basic concepts 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.

ULO2: Competently use modern computing software to model a range of phenomena in science and engineering, displaying the complexity that can occur with nonlinear systems.

ULO3: Demonstrate an 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.

ULO4: 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.

General Assessment Information

REQUIREMENTS TO PASS THIS UNIT

To pass this unit you must: Achieve a total mark equal to or greater than 50%.

LATE SUBMISSION OF WORK: All assessment tasks must be submitted by the official due date and time. Should these assessments be missed due to illness or misadventure, students should apply for Special Consideration. Assessments not submitted by the due date will receive a mark of zero.

The submission time for all uploaded assignments is 11:55 pm. A 1-hour grace period will be provided to students who experience a technical concern.

SPECIAL CONSIDERATION The Special Consideration Policy aims to support students who have been impacted by shortterm circumstances or events that are serious, unavoidable and significantly disruptive, and which may affect their performance in assessment. Assignments: If you experience circumstances or events that affect your ability to complete the written assignments in this unit on time, please inform the convenor and submit a Special Consideration request through ask.mq.edu.au.

Assessment Tasks

Name	Weighting	Hurdle	Due
Assignment 1	15%	No	Week 5

Name	Weighting	Hurdle	Due
Assignment 2	15%	No	Week 9
Assignment 3	10%	No	Week 12
Final Examination	60%	No	Final Exam Period

Assignment 1

Assessment Type [1]: Problem set
Indicative Time on Task [2]: 9 hours
Due: **Week 5**
Weighting: **15%**

The assignment will test the ability of the students to develop and analyse mathematical problems using concepts and techniques learnt in lectures.

On successful completion you will be able to:

- Explain the principles and basic concepts 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.
- Competently use modern computing software to model a range of phenomena in science and engineering, displaying the complexity that can occur with nonlinear systems.
- Demonstrate an 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.
- 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.

Assignment 2

Assessment Type [1]: Problem set
Indicative Time on Task [2]: 9 hours
Due: **Week 9**
Weighting: **15%**

The assignment will test the ability of the students to develop and analyse mathematical

problems using concepts and techniques learnt in lectures.

On successful completion you will be able to:

- Explain the principles and basic concepts 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.
- Competently use modern computing software to model a range of phenomena in science and engineering, displaying the complexity that can occur with nonlinear systems.
- Demonstrate an 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.
- 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.

Assignment 3

Assessment Type [1]: Problem set
Indicative Time on Task [2]: 9 hours
Due: **Week 12**
Weighting: **10%**

The assignment will test the ability of the students to develop and analyse mathematical problems using concepts and techniques learnt in lectures.

On successful completion you will be able to:

- Explain the principles and basic concepts 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.
- Competently use modern computing software to model a range of phenomena in science and engineering, displaying the complexity that can occur with nonlinear systems.
- Demonstrate an 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.
- 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.

Final Examination

Assessment Type [1]: Examination
Indicative Time on Task [2]: 18 hours
Due: **Final Exam Period**
Weighting: **60%**

This will be an invigilated exam, held during the final exam period. It will test the ability of students to utilise concepts and techniques learnt in lectures. The final examination is a hurdle requirement. To satisfy the hurdle requirement students must score at least 50% on the final examimnation.

On successful completion you will be able to:

- Explain the principles and basic concepts 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.
- Competently use modern computing software to model a range of phenomena in science and engineering, displaying the complexity that can occur with nonlinear systems.
- Demonstrate an 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.
- 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.

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[1] If you need help with your assignment, please contact:

- the academic teaching staff in your unit for guidance in understanding or completing this type of assessment
- the Writing Centre for academic skills support.

[2] Indicative time-on-task is an estimate of the time required for completion of the assessment task and is subject to individual variation

Delivery and Resources

CLASSES Lectures (beginning in Week 1): There are two one-hour lectures each week. SGTA classes (beginning in Week 2): Students must register in and attend at least one one-hour class per week.

SGTAs: Led by an SGTA instructor, students will discuss problems related to the previous week's lecture content, and work through similar problems. Off-shore students must email the convenor as soon as possible to discuss study options.

TEXTBOOKS: There is no set textbook for MATH3902. The following texts provide useful references for various sections of the course:

- Hirsch, M.W., Smale S. & Devaney, R.L., *Differential Equations, Dynamical Systems & An Introduction to Chaos*, Elsevier Academic Press. (Available online via the library.)
- Drazin, P.G., *Nonlinear Systems*, Cambridge University Press.
- Strogatz. S. *Nonlinear dynamics with chaos.* Westview Press. (Available online via the library.)
- Salinelli, E. *Discrete dynamical models. Springer.* (Available online via the library.)

COMMUNICATION We will communicate with you via your university email or through announcements on iLearn. Queries to convenor can either be placed on the iLearn discussion board or sent to your lecturers from your university email address.

COVID Information For the latest information on the University's response to COVID-19, please refer to the Coronavirus infection page on the Macquarie website: https://www.mq.edu.au/about/coronavirusfaqs. Remember to check this page regularly in case the information and requirements change during semester. If there are any changes to this unit in relation to COVID, these will be communicated via iLearn.

Unit Schedule

Week	Material	Assessment Due
1	*Discrete Dynamical Systems*: Introduction	
2	*Discrete Dynamical Systems*: Equilibrium points & Stability	
3	*Discrete Dynamical Systems*: Equilibrium points & Stability, continued	
4	*Discrete Dynamical Systems*: Periodic orbits, Sharkovskii's Theorem	
5	*Discrete Dynamical Systems*: Bifurcations, Period doubling, and Stability	Assignment 1 due
6	*Continuous Dynamical Systems*: Introduction, Autonomous Systems	

Week	Material	Assessment Due
7	*Continuous Dynamical Systems*: Autonomous Systems	
8	*Discrete Dynamical Systems*: Logistic map, Chaos	
9	*Continuous Dynamical Systems*: Energy	Assignment 2 due
10	*Continuous Dynamical Systems*: Energy, Poincare-Bendixson Theorem	
11	*Continuous Dynamical Systems*: Poincare-Bendixson Theorem	
12	*Continuous Dynamical Systems*: Bifurcations	Assignment 3 due
13	Revision	

Policies and Procedures

Macquarie University policies and procedures are accessible from Policy Central (https://policies.mq.edu.au). 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
- Assessment Procedure
- Complaints Resolution Procedure for Students and Members of the Public
- Special Consideration Policy

Students seeking more policy resources can visit Student Policies (https://students.mq.edu.au/support/study/policies). It is your one-stop-shop for the key policies you need to know about throughout your undergraduate student journey.

To find other policies relating to Teaching and Learning, visit Policy Central (https://policies.mq.edu.au) and use the search tool.

Student Code of Conduct

Macquarie University students have a responsibility to be familiar with the Student Code of Conduct: https://students.mq.edu.au/admin/other-resources/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

Academic Integrity

At Macquarie, we believe academic integrity – honesty, respect, trust, responsibility, fairness and courage – is at the core of learning, teaching and research. We recognise that meeting the expectations required to complete your assessments can be challenging. So, we offer you a range of resources and services to help you reach your potential, including free online writing and maths support, academic skills development and wellbeing consultations.

Student Support

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

The Writing Centre

The Writing Centre provides resources to develop your English language proficiency, academic writing, and communication skills.

- Workshops
- Chat with a WriteWISE peer writing leader
- Access StudyWISE
- Upload an assignment to Studiosity
- Complete the Academic Integrity Module

The Library provides online and face to face support to help you find and use relevant information resources.

- Subject and Research Guides
- Ask a Librarian

Student Services and Support

Macquarie University offers a range of Student Support Services including:

- IT Support
- Accessibility and disability support with study
- Mental health support
- Safety support to respond to bullying, harassment, sexual harassment and sexual assault
- Social support including information about finances, tenancy and legal issues
- Student Advocacy provides independent advice on MQ policies, procedures, and processes

Student Enquiries

Got a question? Ask us via AskMQ, or contact Service Connect.

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.

Changes from Previous Offering

None