MATH332

Nonlinear Dynamics and Chaos

S2 Day 2015

Dept of Mathematics

Contents

General Information

Unit convenor and teaching staff
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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:

Students should demonstrate the knowledge of the particular area of mathematics covered by the course that is continuous and discrete dynamical systems

Understanding of the breadth of the theory of dynamical systems and its role in other fields of mathematical sciences

Ability to formulate and model practical and abstract problems in the field of dynamical systems using a variety of methods

Ability to construct logical, clearly presented and justified mathematical arguments incorporating deductive reasoning especially in the areas covered by the unit

Further developed ability to work effectively, responsibly and safely in the context of theory of dynamical systems

General Assessment Information

Please note the University's Final Examination policy states:

Each student will be responsible for:

- checking the final examination timetable
- adhering to the final examination timetable
- ensuring they are available for the full duration of the final examination period.

The mathematics department cannot reschedule the final examination date to suit the travel and holiday arrangements of students.

Assessment Tasks

Name	Weighting	Due
Four assignments	20%	Weeks 4, 6, 9, and 12
Four assignments	20%	Weeks 5, 7, 11, and 13
Final examination	60%	University Examination Period

Four assignments

Due: **Weeks 4, 6, 9, and 12**
Weighting: **20%**

Four assignments - Continuous systems

On successful completion you will be able to:

- Students should demonstrate the knowledge of the particular area of mathematics covered by the course that is continuous and discrete dynamical systems
- Understanding of the breadth of the theory of dynamical systems and its role in other fields of mathematical sciences
- Ability to formulate and model practical and abstract problems in the field of dynamical systems using a variety of methods
- Ability to construct logical, clearly presented and justified mathematical arguments incorporating deductive reasoning especially in the areas covered by the unit
- Further developed ability to work effectively, responsibly and safely in the context of theory of dynamical systems

Four assignments

Due: **Weeks 5, 7, 11, and 13**
Weighting: **20%**

Four assignments - Discrete systems

On successful completion you will be able to:

- Students should demonstrate the knowledge of the particular area of mathematics covered by the course that is continuous and discrete dynamical systems
- Understanding of the breadth of the theory of dynamical systems and its role in other fields of mathematical sciences
- Ability to formulate and model practical and abstract problems in the field of dynamical systems using a variety of methods
- Ability to construct logical, clearly presented and justified mathematical arguments incorporating deductive reasoning especially in the areas covered by the unit
- Further developed ability to work effectively, responsibly and safely in the context of theory of dynamical systems

Final examination

Due: **University Examination Period**
Weighting: **60%**

-
On successful completion you will be able to:

- Students should demonstrate the knowledge of the particular area of mathematics covered by the course that is continuous and discrete dynamical systems
- Understanding of the breadth of the theory of dynamical systems and its role in other

fields of mathematical sciences
- Ability to formulate and model practical and abstract problems in the field of dynamical systems using a variety of methods
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Delivery and Resources

Classes

Lectures: you should attend two hours of each lecture stream each week, making a total of four hours.

Required and Recommended Texts and/or Materials

No single textbook is entirely satisfactory for MATH332. The following texts provide useful references for various sections of the course:

- Jordan, D.W. and Smith, P., *Nonlinear Ordinary Differential Equations*, Oxford University Press, 3rd Ed., 1999 (QA372.J58/1999).
- Drazin, P.G., *Nonlinear Systems*, Cambridge University Press, 1992 (QA374.S86/1992).
- Banks, J., Dragan, V. & Jones, A., *Chaos: a mathematical introduction*, Cambridge University Press, 2003 (QA614.8.B36 2003).
- Arrowsmith, D.K. and Place, C.M., *Dynamical Systems*, Chapman and Hall, 1992 (QA614.8.A774/1992).
- Baker, G.L. & Gollub, J.P., *Chaotic Dynamics*, Cambridge University Press, 1990 (QA862.P4.B35/1990).
- Strogatz, S.H., *Nonlinear Dynamics and Chaos*, Addison Wesley, 1994.
- Verhulst, F., *Nonlinear Differential Equations and Dynamical Systems*, Springer-Verlag.
- Elaydi, S. N., Discrete Chaos, Chapman and Hall.

Technology Used and Required

Students are expected to have access to an internet enabled computer with a web browser and Adobe Reader software. Several areas of the university provide wireless access for portable computers. There are computers for student use in the Library and in the Numeracy Centre (C5A 255).

Difficulties with your home computer or internet connection do not constitute a reasonable excuse for lateness of, or failure to submit, assessment tasks.

Unit Schedule

Week	Continuous	Discrete
1	Introduction	Stability of one-dimensional maps
2		
3	Mechanical systems	
4	Linearisation	Bifurcation and Sharkovsky's Theorem
5	Limit cycles	
6		
7	Averaging methods	Chaos in one dimension
8		
9	Poincare Bendixson Theorem	
10	Bifurcation	Stability of two-dimensional maps
11		
12		
13	**Revision**	

This table is a rough guide to the timing of the material in MATH332. Please note that the order and weeks of topics is likely to change.

Learning and Teaching Activities

Lectures

There will be two, two hours long lectures per week. During these the content of the unit will be explained and example problems will be solved and applications in other disciplines discussed.

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.html

Grading Policy http://mq.edu.au/policy/docs/grading/policy.html

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

Grievance Management Policy http://mq.edu.au/policy/docs/grievance_management/policy.html

Disruption to Studies Policy http://www.mq.edu.au/policy/docs/disruption_studies/policy.html *The Disruption to Studies Policy is effective from March 3 2014 and replaces the Special Consideration Policy.*

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.

Solutions will be posted soon after assignments are due. No assignments can be accepted once solutions have been posted. A student who is unable to submit an assignment on time should do the assignment anyway (without submitting it), since that's the way to learn Mathematics; a mark of zero will be awarded for the assignment, except for cases where an application for special consideration is made and approved.

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://informatics.mq.edu.au/help/.

When using the University's IT, you must adhere to the Acceptable Use 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

- Students should demonstrate the knowledge of the particular area of mathematics covered by the course that is continuous and discrete dynamical systems
- Ability to formulate and model practical and abstract problems in the field of dynamical systems using a variety of methods
- Ability to construct logical, clearly presented and justified mathematical arguments incorporating deductive reasoning especially in the areas covered by the unit
- Further developed ability to work effectively, responsibly and safely in the context of theory of dynamical systems

Assessment tasks

- Four assignments
- Four assignments
- 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

- Students should demonstrate the knowledge of the particular area of mathematics covered by the course that is continuous and discrete dynamical systems
- Understanding of the breadth of the theory of dynamical systems and its role in other fields of mathematical sciences
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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

- Students should demonstrate the knowledge of the particular area of mathematics covered by the course that is continuous and discrete dynamical systems
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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

- Students should demonstrate the knowledge of the particular area of mathematics covered by the course that is continuous and discrete dynamical systems
- Understanding of the breadth of the theory of dynamical systems and its role in other fields of mathematical sciences
- Ability to formulate and model practical and abstract problems in the field of dynamical systems using a variety of methods
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Assessment tasks

- Four assignments
- Four assignments
- 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

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- Understanding of the breadth of the theory of dynamical systems and its role in other fields of mathematical sciences
- Ability to formulate and model practical and abstract problems in the field of dynamical systems using a variety of methods
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Assessment tasks

- Four assignments
- Four assignments
- 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

- Students should demonstrate the knowledge of the particular area of mathematics covered by the course that is continuous and discrete dynamical systems
- Ability to formulate and model practical and abstract problems in the field of dynamical systems using a variety of methods
- Ability to construct logical, clearly presented and justified mathematical arguments incorporating deductive reasoning especially in the areas covered by the unit
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Assessment tasks

- Four assignments
- Four assignments

- 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

- Ability to formulate and model practical and abstract problems in the field of dynamical systems using a variety of methods
- Ability to construct logical, clearly presented and justified mathematical arguments incorporating deductive reasoning especially in the areas covered by the unit
- Further developed ability to work effectively, responsibly and safely in the context of theory of dynamical systems

Assessment tasks

- Four assignments
- Four assignments
- 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 dynamical systems and its role in other fields of mathematical sciences
- Further developed ability to work effectively, responsibly and safely in the context of theory of dynamical systems

Assessment tasks

- Four assignments

- Four assignments

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

- Further developed ability to work effectively, responsibly and safely in the context of theory of dynamical systems

Assessment tasks

- Four assignments
- Four assignments

Extra requirements

Satisfactory performance on supervised assessment tasks, such as tests and the final exam, is necessary to pass this unit. If there is a significant difference between a student's marks on supervised assessment tasks and on unsupervised assessment tasks, the scaling of these tasks may be adjusted when determining the final grade, to reflect more appropriately that student's performance on supervised tasks.

Changes since First Published

Date	Description
16/07/2015	no change