MODULE TITLE	**Computational Nonlinear Dynamics**	**CREDIT VALUE**	**15**
MODULE CODE	**MTH3039**	**MODULE CONVENER**	**Dr James Rankin (Coordinator)**

DURATION: TERM	**1**	**2**	**3**
DURATION: WEEKS	**11**	**0**	**0**

Number of Students Taking Module (anticipated)	**19**

DESCRIPTION - summary of the module content

Most mathematical problems in engineering and science lead to systems of nonlinear equations that cannot be solved with pencil and paper, and where a numerical approach does not give a complete answer. In this module you will use theory and mathematical methods from Stages 1 and 2 (calculus, dynamics, differential equations, numerics and scientific computing) to solve realistic problems as they occur in nonlinear dynamics in engineering and science.
In this module you will gradually assemble a toolbox of small programs (in MATLAB) and then use these programs to study nonlinear dynamical systems with complicated behaviour (for example, chaos) and transitions between behaviours (bifurcations) as parameters are changed. In the end you will have solved some fairly complex problems from scratch, using tools developed and written by yourself during the module. For example, you will have proved (or, at least given robust numerical evidence for) the existence of chaos in the forced pendulum and examined the dynamics of some neuron models. Half of the contact time will be supervised lab sessions during which you will get support to get started on the problems. Additional programming experience is recommended for students taking this module.

Pre-requisites: MTH2005 Modelling: Theory and Practise **OR** MTH1003 Mathematical Modelling

AIMS - intentions of the module

You will learn to combine your previously acquired knowledge from Stages 1 and 2 (specifically calculus and modelling) and your programming skills to solve nonlinear problems as they occur in real-world applications, for example, in mechanics, lasers, climate, ecology, chemistry, biology, neuroscience or electronic circuitry.

The problems will all come from applications encountered in academic research (e.g., lasers, mechanical systems, population dynamics, fluid dynamics). The module does NOT intend to teach you how to use particular state-of-the-art research tools (such as AUTO), but will rather guide you to develop idealized versions of these tools from scratch. The module will give you the opportunity to solve problems that are beyond the reach of exam-based assessment but short of individual research projects.

INTENDED LEARNING OUTCOMES (ILOs) (see assessment section below for how ILOs will be assessed)

On successful completion of this module ***you should be able to***:

Module Specific Skills and Knowledge

1. solve high-dimensional nonlinear systems that depend on parameters

2. apply mathematical and computational methods previously learned to study dynamical systems from applications

Discipline Specific Skills and Knowledge

3. solve mathematical problems of medium complexity (that is, requiring combination of a range of computational and mathematical techniques)

Personal and Key Transferable / Employment Skills and Knowledge

4. apply computational and programming skills to problem-solving

5. develop a project independently and with appropriate time management.

SYLLABUS PLAN - summary of the structure and academic content of the module

- Implicit function theorem and Newton iteration in arbitrary dimensions;

- Numerical differentiation and numerical solution of initial-value problems of ODEs in arbitrary dimensions;

- Solution of parameter-dependent nonlinear problems;

- Computation and visualisation of phase portraits and their structural stability;

- Finding and tracking singularities (bifurcations: saddle-node and Hopf bifurcations);

- [*] Regularity and discretisation of ODE boundary-value problems;

- [*] Tracking of periodic orbits, starting from a Hopf bifurcation, and some of their bifurcations;

- [*] computation of basins of attraction for equilibria of autonomous systems or periodic points of periodically forced systems;

- [*] Lyapunov exponents, stable and unstable manifolds of periodic points and detection of their homoclinic tangles in periodically forced systems.

[*] only a selection of these topics will be covered, varying each year

LEARNING AND TEACHING

LEARNING ACTIVITIES AND TEACHING METHODS (given in hours of study time)

Scheduled Learning & Teaching Activities	33.00	**Guided Independent Study**	117.00	**Placement / Study Abroad**	0.00

DETAILS OF LEARNING ACTIVITIES AND TEACHING METHODS

Category	Hours of study time	Description
Scheduled learning and teaching activity	18	Lectures
Scheduled learning and teaching activity	15	Computer lab sessions for work on problems
Guided independent study	87	Independent work on problems
Guided independent study	30	Study of notes and wider reading

ASSESSMENT

FORMATIVE ASSESSMENT - for feedback and development purposes; does not count towards module grade

N/A (but see feedback for Summative Assessment)

SUMMATIVE ASSESSMENT (% of credit)

Coursework	100	Written Exams	0	Practical Exams	0

DETAILS OF SUMMATIVE ASSESSMENT

Form of Assessment	% of Credit	Size of Assessment (e.g. duration/length)	ILOs Assessed	Feedback Method
Coursework 1	40%	300 lines of code, 500 words documentation (including graphs etc)	All	Ongoing during lab sessions, written after marking
Coursework 2	60%	600 lines of code, 1000 words documentation (including graphs etc)	All	Ongoing during lab sessions, written after marking

DETAILS OF RE-ASSESSMENT (where required by referral or deferral)

Original Form of Assessment	Form of Re-assessment	ILOs Re-assessed	Time Scale for Re-assessment
Coursework 1	Coursework 1	All	Ref/Def Period
Coursework 2	Coursework 2	All	Ref/Def Period

RE-ASSESSMENT NOTES

Reassessment will be by coursework in the failed or deferred element only. For deferred candidates, the module mark will be uncapped. For referred candidates, the module mark will be capped at 40%.

RESOURCES

INDICATIVE LEARNING RESOURCES - The following list is offered as an indication of the type & level of information that you are expected to consult. Further guidance will be provided by the Module Convener

Basic reading:

ELE: http://vle.exeter.ac.uk/

Web based and Electronic Resources:
http://www.dynamicalsystems.org/tu/cm/
Other Resources:

Reading list for this module:

Type	Author	Title	Edition	Publisher	Year	ISBN	Search
Set	Kuznetsov Y	Elements of Applied Bifurcation Theory		Springer		978-0-387-21906-6	[Library]
Set	Allgower EL and Georg K	Introduction to Numerical Continuation Methods		Springer		089871544X	[Library]
Set	Kelley CT	Solving Nonlinear Equations with Newtons Method		SIAM		0-89871-546-6	[Library]

CREDIT VALUE	15	ECTS VALUE	7.5

PRE-REQUISITE MODULES	None
CO-REQUISITE MODULES	None

NQF LEVEL (FHEQ)	6	AVAILABLE AS DISTANCE LEARNING	No
ORIGIN DATE	Tuesday 10 July 2018	LAST REVISION DATE	Thursday 26 January 2023

KEY WORDS SEARCH	None Defined