PX391-7.5 Nonlinearity, Chaos and Complexity

21/22

Department
Physics
Level
Undergraduate Level 3
Module leader
Sandra Chapman
Credit value
7.5
Module duration
5 weeks
Assessment
100% exam
Study location
University of Warwick main campus, Coventry

Description

Introductory description

The module introduces non-linear phenomena in science. Examples from physics, chemistry and biology are discussed (little previous knowledge of these subjects will be assumed).

A discussion of phase transitions and the elements of bifurcation theory is followed by the theory of first and second order non-linear differential equations. Such phenomena as simple attractors (limit cycles) are discussed. It is shown how non-linear systems can ‘self-organize’ to produce structures which have interesting time and space dependences. The main ideas from the theory of chaos will are introduced using one-dimensional difference equations as working examples.

[Module web page]

Module aims

To introduce non-linearity and its treatment in scientific modelling.

Outline syllabus

This is an indicative module outline only to give an indication of the sort of topics that may be covered. Actual sessions held may differ.

1. General introduction to Non-Linear Phenomena and universality.
2. Landau theory of phase transitions, order parameters, Bifurcation diagrams. First and second order phase transitions.
3. First order non-linear differential equations. Fixed points and linear stability analysis. Global stability (1D phase plane).
4. Second order non-linear differential equations. Phase plane analysis and classification of fixed points. Limit cycles (Attractor).
5. Difference Equations and maps. The tent map and global chaos, Lyapunov exponents. The logistic map, fixed points and bifurcation sequence to chaos. Feigenbaum universality.
6. Self organisation, and emergent behaviour many degrees of freedom systems. Examples by computer: avalanche and forest fire models, preferential attachment, flocking, segregation. Concept of few order parameters, critical behaviour, phase transitions and scaling.

Learning outcomes

By the end of the module, students should be able to:

- Obtain basic qualitative features of the solutions of first and second order non-linear ordinary differential equations
- Explain how simple, but non-linear, equations can describe complicated (chaotic) behaviour. They should be able to analyse this behaviour
- Work with the concepts describing emergent behaviour in complex systems. (computer algorithms).

Indicative reading list

G Rowlands, Non-Linear Phenomena in Science and Engineering, Ellis Horwood

View reading list on Talis Aspire

Subject specific skills

Knowledge of mathematics and physics. Skills in modelling, reasoning, thinking.

Transferable skills

Analytical, communication, problem-solving, self-study

Study

Study time

Type	Required
Lectures	15 sessions of 1 hour (20%)
Private study	60 hours (80%)
Total	75 hours

Private study description

Working through lecture notes, solving problems, wider reading, discussing with others taking the module, revising for exam, practising on past exam papers

Costs

No further costs have been identified for this module.

Assessment

You must pass all assessment components to pass the module.

Assessment group B1

	Weighting	Study time
In-person Examination	100%	
Answer 2 questions from 3		

- Answerbook Green (8 page)

Feedback on assessment

Personal tutor, group feedback

Past exam papers for PX391

Availability

Courses

This module is Option list A for:

- UPXA-F300 Undergraduate Physics (BSc)
    - Year 3 of F300 Physics

    - Year 3 of F300 Physics
    - Year 3 of F300 Physics
- Year 3 of UPXA-F303 Undergraduate Physics (MPhys)
- Year 4 of UPXA-F301 Undergraduate Physics (with Intercalated Year)

This module is Option list B for:

- Year 3 of UPXA-F303 Undergraduate Physics (MPhys)