National Cheng Kung University
Modular Course 2025 Summer Program

Academic Year：114, Semester：1 Category：Natural and Engineering Sciences

混沌理論簡介
Introduction to Chaos Theory

Instructor	Affiliation	Graduation (Ph.D.)
Yasutaro Nishimura	**Institute of Space and Plasma Sciences**	**University of**
nishimura@pssc.ncku.edu.tw	**National Cheng Kung University**	**Wisconsin-Madison, USA**

Category	Course Credit	Student Size (Maximum)
Natural and Engineering Sciences	**1**	**12**

Student Background

College of Science,
College of Engineering,
College of Bioscience and Biotechnology,
College of Electrical Engineering and Computer Science,
College of Medicine,
College of Planning and Design,
College of Social Sciences

Difficulty

☐ **Challenging** ☐ **Moderately Difficult** ■ **Medium** ☐ **Entry Level (Basic)**

Format of The Course

Lecture 80%, Hands-on Practice 10%, Discussion 10%

Grading Policy

Exam 30%: Short Quiz on basic mechanics problems discussed in the class (~ 60min on Thursday).
Presentation 70%: Two homework sets.

One due on Wednesday and the other due on Monday after the class week. Discussions on the homework problem initiates during the exercise hours at the end of each day (for about 40minutes).

Code of Conduct for The Course

Freshman level mathematics

Course Description

A binary collision of two particles is reversible. We can understood that intuitively if we take a video. Reversing the video, the dynamics appears natural to us. Nothing strange. Newton equation itself is reversible; the form of the equation m d^2x/dt^2 =F does not change its form under an operation setting "t" to "-t". However, we also know from our daily life experiences that gas molecules (imagine a balloon containing helium explodes) at the corner of the room "never" returns to the corner with the same concentration. Time only progresses in one direction, from the past to the future. A part of this can be explained by probability (partition the room and consider combinations). That does not require the notion of the collisions, however. Even if the molecules are penetrating each other, probabilistically

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speaking they never return to the original state. Chaos offers higher degrees of mixing, leading to irreversibility as what we perceive. An infinitesimal difference of initial conditions can diverge exponentially by repetitive binary collisions, resulting in loss of memory (note that there is no hard sphere collision - even neutral atoms/molecules collide electrostatically). In this course, we introduce simple (but actual physics phenomena based) models both in Hamiltonian (energy conserving) and dissipative systems. We then define and discuss chaos in the dynamical systems, hoping that insights can be given to the students regarding the origin of time irreversibility.

Keywords：Chaos, Lyapunov exponents, binary collisions, diffusion, time irreversibility.

Timetable and Syllabus

Period	Timetable	Syllabus
2025/06/30(Mon)	13:00-17:00	Introduction to chaos. Lyapunov exponents.
2025/07/1(Tue)	13:00-17:00	Hamiltonian chaos. Difference between random motion.
2025/07/2(Wed)	13:00-17:00	Gaussian process (cumulants as a measure) and Markov process (correlation damping as a measure).
2025/07/3(Thu)	13:00-17:00	Dissipative chaos. Duffing equation. Lorenz equation. 60 min quiz.
2025/07/4(Fri)	13:00-17:00	A three body problem as an example of non-integrable system.

Goal of the Course

1. Understand the origin of chaos in Hamiltonian (energy conserving) and dissipative system.
2. Learn the definition of chaos and how it can be diagnosed quantitatively.
3. Realize the contemporary view of diffusive phenomena, and time irreversibility.

The Importance, Cross-Over Disciplinary and Contemporary of The Curriculum

Chaos theory shares common interest in nonlinear dynamics in general, weather prediction, fluid turbulence, and sociological problem (population cycles and traffic engineering), to name a few.

Remarks

Sample codes demonstrating chaos will be provided in Phython and C (ANSI C).
Programming skills are not required in the course, but students can still learn as an option.

本課程若因天災等不可抗力之因素或中央、地方政府公告停課，授課教師需依情況依建議補課方式調整課程進度與補課；若需使用假日、國定假日補課，則需與所有修課學生達成共識方能用例假日補課。

建議補課方式：
1. 線上授課方式補課；
2. 當預期可能會因天災(颱風、超大豪雨…等)宣佈停課時，建議老師先行調整加快課程進度或預先增加可能天氣預警之前幾次課程時數；
3. 停課後隔天起延後下課，補足停課延誤的進度；若停課超過 1 天，則在開始上課後延後下課補課，或當週星期六、日補課；

更改課程授課方式，例如：DEMO 改以考試、報告、作業取代。