

National Cheng Kung University

Modular Courses 2026 Summer Program

Academic Year : 115, Semester : 1

Category : Natural and Engineering Sciences

混沌理論簡介

Introduction to Chaos Theory

Instructor		Affiliation	Graduation (Ph.D.)
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Course Type	Course Credit	Student Size (Maximum)	
Lecture + Recitation	1	25	

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

- 問題考試 30% :
Short Quiz on basic mechanics problems discussed in the class (~ 60min on Thursday). 周四安排一次課堂上討論的基本力學問題Quiz，時間60分鐘。
- 報告 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). 兩份作業，一份在周三繳交，另一份課程結束後的周一繳交。每天課程最後40分鐘為演習時間，作業問題可在演習時間的討論。

Code of Conduct for The Course

Freshman level mathematics.

Course Description

A binary collision of two particles is reversible. We can understand 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 $m \frac{d^2x}{dt^2} = F$ 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 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

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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.

兩個粒子的二元碰撞是可逆的。如果我們拍個視頻，我們就能直觀地理解這一點。倒轉視頻，動態對我們來說顯得很自然。沒什麼奇怪的。牛頓方程式本身是可逆的；方程式 $m \frac{d^2x}{dt^2} = F$ 的形式在「t」設定為「-t」的運算下保持不變。然而，我們從日常生活經驗中也知道，房間角落的氣體分子（想像氬氣球爆炸）「永遠不會」以相同的濃度回到角落。在這樣的系統時間只向一個方向前進，從過去到未來逆轉時間「-t」和「t」兩者動力方程式並不相同，這不可逆現象的一部份可以用機率來解釋（劃分房間並考慮組合），且並不需要碰撞的概念。即使分子相互滲透，從機率上講它們也永遠不會回到原來的狀態。「混沌理論」則提供了更高程度的系統狀態混雜，可讓我們感知到不可逆轉性。初始條件的無窮小差異可以因為重複的二元碰撞而呈指數發散，從而導致系統對過去狀態的記憶丟失（請注意，不存在硬球體碰撞 - 即使中性原子/分子也可發生靜電碰撞）。在本課程中，我們介紹哈密頓系統（能量守恆）和耗散系統(dissipative systems)中基於物理的模型。然後，我們定義並討論動力系統中的混沌，希望能為學生提供關於時間不可逆性起源的洞見觀點。

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

關鍵字：混沌、Lyapunov指數、二元碰撞、擴散、時間不可逆轉。

Timetable and Syllabus

Period	Timetable	Syllabus
6/29(Mon)	14:00-17:40	Introduction to chaos. Lyapunov exponents.
6/30(Tue)	14:00-17:40	Hamiltonian chaos. Difference between random motion.
7/1(Wed)	14:00-17:40	Gaussian process (cumulants as a measure) and Markov process (correlation damping as a measure).
7/2(Thu)	14:00-17:40	Dissipative chaos. Duffing equation. Lorenz equation. 60 minutes quiz.
7/3(Fri)	14:00-17:40	The three body problem in celestial mechanics and charged particle dynamics.

Goal of the Course

1. Understand that 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.

混沌理論在一般來說非線性動力學、天氣預報、流體湍流，和社會學問題（人口週期和交通工程）等方面有著共同的興趣。

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Remarks

- Sample codes demonstrating chaos will be provided in Python and C (ANSI C).
- Programming skills are not required in the course, but students can still learn as an option.
- Teaching materials:
Hand written and typed notes will be uploaded to moodle.

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。