

Introduction to Nonlinear Dynamics (SC401)
Mid-Semester Examination Syllabus – Autumn Semester, 2023

Course covered in the class notes:

1. Introduction to the course and its overview.
2. Basic principles of differential equations (ordinary and partial). Orders of differential equations. First order linear systems of one variable. Rate \propto state. Transformation of variables, separation of variables.
3. Rescaling into dimensionless forms. Scales, approximations and basic plotting techniques ($\dot{x} = a - bx$).
4. Solution and plotting of $\dot{x} = a + bx$. Stokes's law of terminal velocity.
5. Atomic waste disposal.
6. Viscoelastic deformation of rocks. The Duckworth-Lewis method in cricket.
7. Radioactivity. Radioactive series.
8. Detecting art forgery. Radio-carbon dating. Q-R-C circuit. Flows on the line.
9. Phase plots, fixed points (equilibrium points), attractors and repellers. Basic examples of phase portraits.
10. The logistic equation, its integral solution, graph plotting and its phase portrait.
11. Plotting quadratic autonomous functions. Phase portraits of critical cases and half-stable fixed points.
12. Plotting of a polynomial series and a cubic polynomial.
13. Fixed points in an autonomous transcendental function. Linear stability analysis and small perturbations. The critical condition and power-law convergence.
14. Testing the stability of fixed points. Higher orders of nonlinearity. The Fermi-Dirac form of equation.
15. Modifications of the logistic equation. Nonlinear non-autonomous systems. Power laws and Zipf's law.
16. Population dynamics. The Malthusian law and logistic modelling of demographics. Country-wise examples.
17. Policy implications of the logistic modelling and its criticisms.
18. The laws of social dynamics. Example of sharks and salmon.
19. Critical population growth of New York city. Turbulence. Free fall of a parachutist.
20. Item response theory. Sigmoid functions in neuron activity and positive cooperativity in haemoglobin. Power laws and their properties.
21. Spread of agricultural innovations. Taylor expansion in three variables.
22. Spread of industrial innovations. Growth of free living dividing cells. Gompertz law of tumour growth.
23. Bacteria versus toxin. The p-n junction diode. Phase plots of linear and nonlinear practical examples.
24. Phase plots of nonlinear (non-logistic type) practical examples. Autocatalysis. The Allee effect.¹

¹PTO

Books:

1. *Nonlinear Dynamics and Chaos: Steven Strogatz* – Chapter 1: Sections 1.0, 1.1, 1.2, 1.3 (general reading). Chapter 2: Sections 2.0, 2.1, 2.2, 2.3, 2.4, 2.5 and 2.6 (focus on the exercises of Sections 2.2, 2.3 and 2.4).
 2. *Differential Equations and Their Applications: Martin Braun* – Chapter 1: Sections 1.3 (at the end of the section go through the brief note on C-14 dating that follows Question 6, and the problems in Questions 7 & 8), 1.5 (also Questions 7 & 8 at the end of the section), 1.6, 1.7 and 1.8.
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