Indian Institute of Technology Kanpur
Proposal for a New Course

1. Course No: **CHE6XX (proposed)**

2. Course Title: **Stability Theory for Chemical Engineers**

3. Per Week Lectures: **3** (L), Tutorial: **0** (T), Laboratory: **0** (P), Additional Hours[0-2]: **0** (A),

   Credits (3-0-0-0): **9** Duration of Course: **One Semester**

4. Proposing Department: **Department of Chemical Engineering**

   Other Departments/IDPs which may be interested in the proposed course: **NA**

   Other faculty members interested in teaching the proposed course: **Dr. Naveen Tiwari, Dr. V. Shankar**

5. Proposing Instructor(s): **Dr. Dipin S. Pillai**

6. Course Description:

   A. Objectives:
   The objective of this course is to familiarize students with the applications of nonlinear dynamics and stability theory in various aspects of core chemical engineering.

   B. Contents (preferably in the form of 5 to 10 broad titles):
   Lecture-wise break-up (considering the duration of each lecture is 50 minutes)

S. No.	**Broad Title**	**Topics**	**No. of Lectures**
1.	Introduction	Introduction to nonlinear dynamics and stability theory	1
2.	1D Systems	Lumped Parameter Systems: ODEs, Flows on a line, Bifurcations: Saddle-node, transcritical, pitchfork	4
3.	2D Systems	Fixed points, phase plane, eigenvalues, eigenvectors, conservative systems, Lotka-Volterra type models, conservative systems	5
4.	Limit Cycles	Hopf bifurcation, index theory, existence of closed orbits, Poincaré–Benedixson theorem, van der Pol oscillator, method of multiple time scales	6
8.	Non-isothermal reactors	Multiplicity, stability, steady states and limit cycles in non-isothermal CSTRs with and without Frank-Kamenetskii approximation	4
5.	Homotopy Continuation, MATCONT 7.4	Bifurcation diagrams using the method of homotopy continuation, Brief introduction session to MATCONT 7.4	3
6.	Multi-component Distillation	Residue curve maps, stationary points: stability of pure component and azeotropic compositions, distillation boundary, bifurcations under finite reflux	5

7.	Oscillating Reactions	Beluosov–Zhabotinsky reaction, Oregonator model and its limit cycles	3
9.	Distributed Parameter Systems	PDEs as governing equations, introduction to modal analysis, dispersion relations, classification of linear instability of a spatially uniform state: Type I-III, multiplicity and stability of PFRs	5
9.	Reaction-Diffusion Systems	Turing patterns, Spatiotemporal oscillations of chemical oscillators	4
		Total	40

C. Recommended pre-requisites, if any: **CHE212, CHE213, CHE331**

D. Short summary for including in the Courses of Study Booklet:
Introduction to stability theory, lumped parameter systems with ODEs, saddle-node, transcritical, pitchfork bifurcations, 2D Systems - fixed points, phase plane, eigenvalues, eigenvectors, conservative systems, Lotka-Volterra, limit cycles, non-isothermal CSTR, multi-component distillation, residue curve maps, distillation boundary, oscillating reactions, distributed parameter systems with PDEs, modal analysis, dispersion relations, Turing patterns, stability of PFR, spatiotemporal chemical oscillations

7. Recommended text/reference books:

- **Strogatz SH. Nonlinear dynamics and chaos: with applications to physics, biology, chemistry, and engineering. CRC press; 2018.**
- **Perlmutter DD. Stability of Chemical Reactors. Prentice-Hall; 1972.**
- **Doherty MF, and Malone MF. Conceptual Design of Distillation Systems. McGraw-Hill, 2001.**
- **Cross M, Greenside H. Pattern formation and dynamics in nonequilibrium systems. Cambridge University Press; 2009.**
- **Epstein IR, Pojman JA. An introduction to nonlinear chemical dynamics: oscillations, waves, patterns, and chaos. Oxford university press; 1998.**

8. Any other remarks:

- **Computational take-home assignments will be provided to supplement the theoretical aspects.**

Dated: 09/03/24 Proposer: Dr. Dipin S. Pillai

Dated: DPGC Convener:

The course is approved / not approved

Chairman, SPGC

Dated: _____