Indian Institute of Technology, Kanpur

Proposal for a New Course

1. Course No: AE 6XX

2. Course Title: Structural Vibration and Control

3. Per Week Lectures: 3(L), Tutorial: 0 (T), Laboratory: 0 (P), Additional Hours [0-2]: 0 (A), Credits (3*L+2*T+P+A): 9 Duration of Course: Full Semester

4. Proposing Department: Aerospace Engineering
   Other faculty members interesting in teaching the proposed course:

5. Proposing Instructors: Tanmay Mathur and Dipak Giri

6. Course Description:

(A) *Objectives:* The objective of this course is to enable the students to make the link between structural dynamics and vibrations, and control theory instead of studying these topics in isolation. The course begins with formulation of the eigen value problem, converting the vibration problem into the state space form, and then applying control theory for systems where instabilities (such as flutter, torsional vibrations under aerodynamic loads) can lead to catastrophic failures.

(B) *Contents:*

S. No.	Broad Title	Topics	Num. of Lectures
1	Introduction	• Fundamentals of structural dyn. and vibrations • Applications in aerospace industry- cables, beams, plates, rotating machinery • sDOF system and modeling approach	2
2	Modelling	• Energy integrals T, V, W • Elastic strain energy of structural members • Principle of virtual work and Hamilton's principle • Equation of motion and boundary conditions	3
3	Analytical solution methods	• Modal analysis – eigenfrequencies and mode shapes • Examples for cables, beams, driveshaft, airplane wings etc. • Physical interpretation and solution using symbolic math toolbox • Eigen value problem and orthogonality of modes • Transfer function and frequency response – bode plot	6

4	Discretization methods	• Transfer function truncation • Assumed modes method • Galerkin's method • Finite element method – cubic shape functions for beams • Rotating beams and instability (helicopter)	10
5	Classical Control	• Transfer Function Based Control • Effect of noise, disturbance, and reference input in the transfer function • PD, PID control • Time Domain analysis: Transient Response- Effect of natural frequency and damping ratio • Steady-state response: Error analysis. • Stability Criterion: Routh Stability analysis • Root Locus, PID control design. • Compensators: Lead and Lag • Control Synthesis in Frequency domain • Compensators in frequency domain, gain and phase margins, stability analysis.	13
6	Modern Control	• State-space representations: Single-input and Single-Output (SISO), Multiple-Input and Multiple-Output (MIMO). • State-space to transfer function and vice-versa • State-transition matrix, controllability, observability, and canonical forms. • State-feedback control • Observer design • Multivariable controls	5

(C) Pre-requisites: AE 688, AE602 or equivalent

(D) Short summary for including in the courses of Study Booklet: (same as objectives)

7. Recommended Books:
   a. Meirovitch, L., 1991. Dynamics and control of structures. John Wiley & Sons.
   b. Friedmann, P.P., Lesieutre, G.A. and Huang, D., 2023. Structural Dynamics (Vol. 50). Cambridge University Press.
   c. Friedland, B., 2012. Control system design: an introduction to state-space methods. Courier Corporation.
   d. Chen, C.T., 1999. Linear System Theory and Design.