國立清華大學
National Tsing Hua University

PME 534200 Advanced Mechanical Vibrations
高等振動學

Fall Semester, 2022

Instructor:	Prof. Jen-Yuan (James) Chang 張禎元 教授 Credits: 3 credits.
Language:	This course will be **offered in English**
Class meetings:	**F1F2F3 Engineering Building I – R217 or virtually online through MS Teams**
Office hours:	Friday 17:00-18:00 PM in Prof. Chang's office
Course description:	The subject area for this course is mechanical vibration, at a level appropriate for master and doctoral graduate students. Classical techniques in mechanical vibration are developed for the modeling and analysis of discrete and continuous linear dynamic systems. Continuous systems are described within the broader context of operator theory to emphasize the physical and mathematical analogies with discrete systems. Specific topics include: *Discrete systems.* Equations of motion for multiple degree of freedom systems through Lagrange's method; linearization about equilibrium; symmetry and definiteness properties; free vibration; matrix eigenvalue problems; orthogonality; Rayleigh quotient; generalized coordinates; transient and forced response through modal analysis. *Continuous systems.* Classical rod, shaft, string, beam, membrane and plate models; Hamilton's principle; equations of motion and boundary conditions through variational methods; essentials of functional analysis; exact solution of eigenvalue problems; Galerkin's method; essential and suppressible boundary conditions; Kamke quotient; introduction to elastic wave propagation and vibrations of rotors.
Prerequisites:	PME 332000 "Mechanical Vibrations," or its equivalent.
Textbooks:	L. Meirovitch, *Analytical Methods in Vibrations*, Macmillan Lecture notes/materials provided by Professor Chang.
References:	S.S. Rao, *Vibration of Continuous Systems*, Wiley. L.A. Pars, *A Treatise on Analytical Dynamics*, Oxbow. F.S. Tse, I.E. Morse, and R.T. Hinkle, *Mechanical Vibrations*, Prentice-Hall. D. Newland, *Mechanical Vibration Analysis and Computation*, Longman.
Teaching Method:	Classroom lectures in English with teaching materials posted in Moodle.
Assessments:	Homework & Labs 30% Term Project 10% Midterm Exams 30% Final Exam 30%
Homework Policy:	Problem sets will be assigned regularly and will usually be due one week later. Usually combination of analytical, computational, and graphical approaches will be expected in homework. Copy of homework is not allowed. However, you are allowed to *discuss* homework problems with one another in order to teach each other how to solve problems. You are NOT allowed to copy work from someone else OR to work step-by-step through a problem with someone else. The work you hand in with your name on it must be your attempt to work through the problem. As a general guideline, oral communication regarding the homework is allowed, whereas written communication is not allowed. Because of the fast pace of the class, please avoid handing in late homework. If homework is submitted after solution set is distributed, 50% of the grade will be taken off.

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Course Outline and Reading Schedule

Discrete Systems:

1. Review of Single Degree of Freedom Systems (Meirovitch, Chapter 1)
    a. Free vibrations
    b. Response through transform methods
    c. Frequency response function
2. Equations of Motion for Multi-Degree of Freedom Systems (Chapter 2, 3)
    a. Definitions and concepts
    b. Derivation of Lagrange's equation
    c. Small oscillations around equilibrium
3. Free Vibration (Chapter 4)
    a. Matrix eigenvalue problems
    b. Properties of the eigenvalue problem
    c. Solution methods
    d. Expansion techniques
    e. Rayleigh's quotient
4. Modal Analysis (Chapter 7.1-7.6 and 9.1-9.5)
    a. Response problems
    b. General solutions
    c. Steady State Harmonic Response
    d. Damped system response
       Mechanism of dissipation; Viscous damping; Rayleigh proportional damping; Modal damping

Continuous Systems:

5. Equations of Motion for Continuous Systems (Course notes and Chapters 5, and 10.1-10.5)
    a. Transition from discrete system to continuous system
    b. Infinitesimal element approach
       Torsional Rod, longitudinal rod, and string models; Euler-Bernoulli, Rayleigh, and Timoshenko Models; Membranes
    c. Variational approach
       Hamilton's principle for a conservative discrete system; Extended Hamilton's principle; Extension to continuous systems; Applications
6. Eigenvalue Problems of Continuous Systems (Course notes and Chapter 5)
    a. Formulation and solution of eigenvalue problems
       One-dimensional, 2nd-order problems; One-dimensional, 4th order problems; Two-dimensional, 2nd-order problems; Two-dimensional, 4th-order problems.
    b. Structure of the eigenvalue problem
       Essentials of functional analysis; Properties of linear operators, symmetric, and positive-definiteness.
7. Modal Analysis (Course notes and Chapter 7.7-7.17)
    a. General development
    b. Steady state harmonic response
    c. Static response
    d. Transformations for inhomogeneous boundary conditions
8. Special topics
    a. Introduction to global discretization (Course notes and Chapter 6.1-6.6)
    b. Introduction to constrained systems (Course notes)
    c. Introduction to elastic wave propagation (Course notes and Chapter 8.1-8.8)
    d. Vibrations of rotors (Course notes)

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