AME 521 Engineering Vibrations II

Fall 2023
Department of Mechanical Engineering
University of Southern California

(Created on 2023-0524; Revised on 2023-0818)

Description: 4 units
Multi-degree of freedom systems; continuous systems; gyroscopic systems; modal analysis; beams, rods, strings, shafts; membranes, plates, and cylindrical shells; numerical methods including Rayleigh Ritz method, Galerkin method, assumed-mode method, and finite element methods; application problems.

Prerequisite: AME 420

Instructor	Professor Bingen (Ben) Yang Office: OHE 412F; Phone: (213) 740-7082; Email: bingen@usc.edu
Class Meeting	Monday and Wednesday 6:00-7:50 pm, OHE 100D
Office Hour	Monday and Wednesday 3:30 – 5:00 pm, in office and Zoom meeting

Course Materials:

William J. Bottega, 2014, Engineering Vibrations, CRC Press, 2nd ed.,
ISBN 9781498723664

Class notes and handouts (downloadable from the AME521 website)

References: [1] S. Graham Kelly, 2006, Advanced Vibration Analysis, CRC.

[2] L. Meirovitch, 2002, *Fundamentals of Vibrations*, McGraw-Hill.

[3] B. Yang, 2023, *Stress, Strain, and Structural Dynamics*, Academic Press.

Grading:

Three (3) online midterm exams (110 mins, 25% each)	75%
Project	25%
No final exam	
Total	100 %

Homework: 10 sets of non-credit homework problems will be assigned weekly. Solutions to the homework will be provided. Timely and independent completion of the homework problems is important to understanding of the course materials, and to good performance in the coursework.

Learning Objectives:

The objectives of this course are:

- To provide students with fundamental theories on linear vibrations for a variety of dynamic systems in a variety of engineering applications;
- To train students on how to apply those theories in modeling, analysis and numerical simulation of vibrating systems; and
- To help students develop skills of handling practical engineering problems.

Topics:

- Review of single-degree-of-freedom systems
- Establishment of equations of motion
    - Newton's laws
    - Lagrange's equations
    - Small oscillation and linearization (two methods)
- Multi-degree-of-freedom systems
    - Spring-mass-damper systems
    - Natural modes of vibration
    - Eigenvalue problems and solutions
    - Steady-state response to harmonic excitations
    - Transient response via modal analysis
    - Damping in vibrating systems
    - General mechanical systems
    - Use of MATLAB in vibration analysis
- State equations and transfer function formulation
    - State equations and solution via eigenvector expansion and numerical integration
    - Transfer function formulation and convolution integral
- Distributed vibrating systems
    - Calculus of variations
    - Hamilton's principles and equations of motion
    - Boundary-initial value problems of strings, rods, shafts and beams
    - Solution of eigenvalue problems
    - Natural normal modes and eigenfunction expansion (modal analysis)
    - Damping in distributed systems
    - Self-adjoint and non-self-adjoint systems
    - Green's function formulation
    - Vibration of membranes
    - Vibration of thin plates
- Approximate methods for distributed systems
    - Rayleigh's quotient
    - Assumed-mode method
- Applications
    - Dynamics of structures carrying moving subsystems
    - Dynamic vibration absorption
    - Flexible rotor-bearing systems

AME 521 Website

All the class notes, handouts, homework assignments and solutions, and project description are paperless. These documents are downloadable from the web https://courses.uscden.net
You can get access to the course materials from the following folders:

"Syllabus" -- syllabus and midterm exam solutions
"Content" -- lecture notes and handouts, homework and solutions, and project description

Course Schedule

Important Dates			
	2023/09/27	Midterm Exam 1 (110 mins)	Online
	2022/11/01	Midterm Exam 2 (110 mins)	Online
	2022/11/29	Midterm Exam 3 (110 mins)	Online
	2022/12/06	Project report due (Wednesday, by 11:59 pm)	Online submission

Week	Date	Materials Covered/Exams	HW/Project
1	8/21	Review of single-degree-of-freedom systems (AME420 course materials) Textbook: Chapters 2-4, pp. 71-250 Class Notes: Chapter 1; Handouts 1a, 1b & 1c	
	8/23	Multi-degree-of-freedom (M-DOF) systems: governing equations by Newtonian approach Textbook: Section 6.1 Class notes: Chapter 2, Handout 2	
2	8/28	M-DOF systems: Lagrange Equations Textbook: Section 6.2 Class notes: Chapter 2	HW 1
	8/30	MDOF systems: linearization, more examples Class notes: Chapters 2 and 3, Handout 3	
3	9/4	Labor Day – No class	
	9/6	MDOF systems: eigenvalue problems Textbook: Sections 7.1-7.2 Class notes: Chapter 3	HW 2
4	9/11	M-DOF systems: eigenvalue problems, free vibration, modal analysis Textbook: Chapter 7 Class notes: Chapters 3 and 4	
	9/13	M-DOF systems: modal analysis Textbook: Chapter 8, Chapter 8 Reference Class notes: Chapter 4	HW 3
5	9/18	M-DOF systems: damped systems Class notes: Chapter 5, Handouts 4 and 5	
	9/20	M-DOF systems: general mechanical systems, steady-state response	HW 4
6	9/25	Calculus of variations Class notes: Chapter 6, Handout 6	

	9/27	**Midterm Exam 1 -- online**	
7	10/2	Extended Hamilton's principle Class notes: Chapter 6	HW 5
	10/4	1-D distributed systems: governing equations Textbook: Sections 9.1-9.6 Class notes: Chapter 7	Project assignment
8	10/9	Eigenvalue problems of 1-D continua Textbook: Sections 10.1-10.7 Class notes: Chapter 7	HW 6
	10/11	Orthogonality of eigensolutions Textbook: Chapter 11 Class notes: Chapter 7	
9	10/16	Modal analysis of 1-D continua, damped 1-D continua, steady-state response Textbook: Chapter 11 Class notes: Chapter 7	HW 7
	10/18	Distributed transfer function method (DTFM) Class notes: Chapter 8 Handouts 7 and 8	
10	10/23	DTFM: eigensolutions of 1-D continua Class notes: Chapter 8	HW 8
	10/25	Approximation methods: Rayleigh quotient, Class notes: Chapter 9 Handouts 9 and 10	
11	10/30	The assumed-mode method, project tips Class notes: Chapter 9	HW 9
	11/1	**Midterm Exam 2 -- online**	
12	11/6	Finite element methods, project tips Class notes: Chapter 9	
	11/8	Application 1: Coupled distributed-lumped systems: combined beams Class notes: Chapter 10a	
13	11/13	Application 2: Structures carrying moving subsystems Class notes: Chapter 10b Handout 11	HW 10
	11/15	Two-dimensional continua: membranes Textbook: Section 12.2 Class notes: Chapter 12a	
14	11/20	Two-dimensional continua: rectangular plates Textbook: Section 12.3 Class notes: Chapter 12b	
	11/22	Thanksgiving Break – No class	
15	11/27	Applications 3 and 4: Dynamic vibration absorption, flexible rotor systems Class notes: Chapter 13 Handout 12	
	11/29	**Midterm Exam 3 – online**	Last class
16	12/6	**Project report due (Wedn., by 11:59 PM)**	