AME 521 Engineering Vibrations II

Fall 2022
Department of Mechanical Engineering
University of Southern California

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 5:00-6:50 pm,
Office Hour	Monday and Wednesday 1:30 am - 3 pm, office and online (Zoom meeting)

Course Materials:

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

Handouts

Class notes (downloadable from the AME521 website)

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

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

[3] Ansel C. Ugural, 2017, Plates and Shells: Theory and Analysis, Fourth Edition

Grading:

Three (3) midterm exams (110 mins, 22% each)	66%
Project	34%
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
    - 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://blackboard.usc.edu/
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			
	2022/09/26	Midterm Exam 1 (110 mins)	Open-book & open notes
	2022/10/26	Midterm Exam 2 (110 mins)	Open-book & open notes
	2022/11/30	Midterm Exam 3 (110 mins)	Open-book & open notes
	2022/12/07	Project report due (Wednesday, by 11:59 pm)	

Week	**Date**	**Materials Covered/Exams**	**HW/Project**
1	8/22	Review of single-degree-of-freedom systems (AME420 course materials) Textbook: Chapters 2-4, pp. 71-250 Class Notes: Chapter 1; Handouts 1a and 1b	
	8/24	Multi-degree-of-freedom (M-DOF) systems: governing equations by Newtonian approach Textbook: Section 6.1 Class notes: Chapter 2, Handout 2	
2	8/29	M-DOF systems: Lagrange Equations Textbook: Section 6.2 Class notes: Chapter 2	HW 1
	8/31	MDOF systems: linearization, more systems Class notes: Chapters 2 and 3, Handout 3	
3	9/5	Labor Day – No class	
	9/7	MDOF systems: eigenvalue problems Textbook: Sections 7.1-7.2 Class notes: Chapter 3	HW 2
4	9/12	M-DOF systems: eigenvalue problems, free vibration, modal analysis Textbook: Chapter 7 Class notes: Chapters 3 and 4	
	9/14	M-DOF systems: modal analysis Textbook: Chapter 8 Class notes: Chapter 4	HW 3
5	9/19	M-DOF systems: damped systems Class notes: Chapter 5, Handouts 4 and 5	
	9/21	M-DOF systems: general mechanical systems, steady-state response	HW 4
6	9/26	**Midterm Exam 1**	

	9/28	Calculus of variations Class notes: Chapter 6, Handout 6	
7	10/3	Extended Hamilton's principle Class notes: Chapter 6	HW 5
	10/5	1-D distributed systems: governing equations Textbook: Sections 9.1-9.6 Class notes: Chapter 7	Project assignment
8	10/10	Eigenvalue problems of 1-D continua Textbook: Sections 10.1-10.7 Class notes: Chapter 7	HW 6
	10/12	Modal analysis of 1-D continua Textbook: Chapter 11 Class notes: Chapter 7	
9	10/17	Damped 1-D distributed systems Distributed gyroscopic systems	HW 7
	10/19	Approximation method: Rayleigh quotient, Class notes: Chapter 8	
10	10/24	Approximation method: the assumed-mode method Class notes: Chapter 8	HW 8
	10/26	**Midterm Exam 2**	
11	10/31	Combined distributed-lumped systems Class notes: Chapter 9, Handouts 7 and 8	
	11/2	Distributed transfer function method (DTFM) for 1-D continua: formulation Class notes: Chapter 10	HW 9
12	11/7	DTFM: eigensolutions Handouts 9 to 12 Research papers	
	11/9	Two-dimensional continua: membranes Textbook: Section 12.2 Class notes: Chapter 11a	
13	11/14	Two-dimensional continua: rectangular plates Textbook: Section 12.3 Class notes: Chapter 11b	HW 10
	11/18	Finite element method Class notes: Chapter 12a	
14	11/21	Finite element method Class notes: Chapter 12b	HW 10 due
	11/23	Thanksgiving Break – No class	
15	11/28	Review of AME521 Tips for the project	
	11/30	**Midterm Exam 3**	Last class
	12/7	**Project report due (Wedn., by 11:59 PM)**	

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