AME 521 Engineering Vibrations II

Fall 2020
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 430; Phone: (213) 740-7082; Email: bingen@usc.edu
Class Meeting	Monday and Wednesday 5:00-6:50 pm, online
Office Hour	Monday and Wednesday 10:30 am -12 noon, online

Text Book: 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) online midterm exams (110 mins, 22% each)	66%
Project	32%
No final exam	
Total	100 %

Homework: Nine (9) sets of non-credit homework problems will be assigned weekly. Timely and independent completion of the homework problems is important to the 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

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

Online Teaching

According to the university policy in dealing with the COVID-19 pandemic, all the activities in this course, including lectures, office hours, homework, project, and midterms, shall be taken online. For this, zoom meetings and the AME521 blackboard website will be used on a daily basis.

Course Schedule

Important Dates			
	2020/09/23	Midterm Exam 1 (110 mins)	Open-book & open notes
	2020/10/21	Midterm Exam 2 (110 mins)	Open-book & open notes
	2020/11/18	Midterm Exam 3 (110 mins)	Open-book & open notes
	2020/12/04	Project report due (Friday, by 11:59 pm)	

Week	Date	Materials Covered/Exams	HW/Project
1	8/24	Review of single-degree-of-freedom systems (AME420 course materials) Class Notes: Chapter 1, Handouts 1a and 1b	
	8/26	Multi-degree-of-freedom (M-DOF) systems: governing equations by Newtonian approach Class notes: Chapter 2, Handout 2	
2	8/31	M-DOF systems: Lagrange Equations Class notes: Chapter 2	HW 1
	9/2	MDOF systems: linearization, more systems Class notes: Chapters 2 and 3, Handout 3	
3	9/7	Labor Day – No class	
	9/9	MDOF systems: eigenvalue problems Class notes: Chapter 3	HW 2
4	9/14	M-DOF systems: eigenvalue problems, modal analysis Class notes: Chapters 3 and 4	
	9/16	M-DOF systems: modal analysis Class notes: Chapter 4	HW 3
5	9/21	M-DOF systems: damped systems Class notes: Chapter 5, Handouts 4 and 5	
	9/23	**Midterm Exam 1**	

6	9/28	M-DOF systems: general mechanical systems, steady-state response	
	9/30	Calculus of variations Class notes: Chapter 6, Handout 6	HW 4
7	10/5	Extended Hamilton's principle Class notes: Chapter 6	Project assignment
	10/7	1-D distributed systems: governing equations Class notes: Chapter 7	HW 5
8	10/12	Eigenvalue problems of 1-D continua	
	10/14	Eigensolutions of 1-D continua	HW 6
9	10/19	1-D distributed systems: modal analysis Class notes: Chapter 7	
	10/21	**Midterm Exam 2**	
10	10/26	Damped distributed systems Approximation method: Rayleigh quotient, Class notes: Chapter 8	HW 7
	10/28	Approximation method: the assumed-mode method Class notes: Chapter 8	
11	11/2	Combined distributed-lumped systems Class notes: Chapter 9, Handouts 7 and 8	HW 8
	11/4	Distributed transfer function method (DTFM) for 1-D continua: formulation Class notes: Chapter 10	
12	11/9	DTFM: eigensolutions Handouts 9 to 12	HW 9
	11/11	Two-dimensional continua: membranes Class notes: Chapter 11a	
13	11/16	Two-dimensional continua: rectangular plates Class notes: Chapter 11b	
	11/18	Introduction to finite element method Review of AME521	
14	11/23	**Midterm Exam 3**	Last class
	12/4	**Project report due (Friday, by 11:59 PM)**	

Created on 2020-0617
Revised on 2020-0806