# AME 521 Engineering Vibrations II

Fall 2025
Department of Mechanical Engineering
University of Southern California

(Created on 2025-0502; Revised on 2025-0506)

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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

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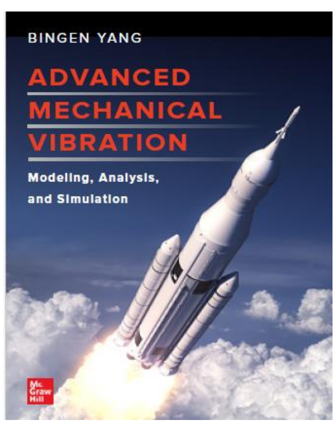
| **Instructor** | Professor Bingen (Ben) Yang<br>Office: OHE 412F; Phone: (213) 740-7082; Email: bingen@usc.edu |
| Class Meeting | Monday and Wednesday 6:00-7:50 pm, RTH 109 |
| Office Hour | Monday and Wednesday 3:30 – 5:00 pm, in office and at Zoom meeting |

**Course Materials:**

Textbook: Bingen Yang, 2025, *Advanced Mechanical Vibration: Modeling, Analysis, and Simulation*, McGraw Hill. (1265989311 · 9781265989316).
[Amazon.com: Advanced Mechanical Vibration: Modeling, Analysis, and Simulation: 9781265989316: Yang, Bingen: Books]




Class Notes: Class notes and handouts (downloadable from the AME521 website)

**AME 521 Website – D2L Brightspace:** https://courses.uscden.net

Contact DEN for any questions on using the website.

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| **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 (50 problems for the entire semester). Solutions to the homework will be provided. Timely and independent completion of the homework problems is important to understanding 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 dynamic systems in a variety of engineering applications;
- To train students on how to apply those theories in modeling, analysis, and simulation of vibrating systems; and
- To help students develop skills of handling practical engineering problems.

**Topics:**

- Review of single-degree-of-freedom systems
- Multi-degree-of-freedom systems: establishment of equations of motion
    - Newton's laws
    - Lagrange's equations
    - Small oscillation and linearization
- Multi-degree-of-freedom systems: eigenvalue problems and modal analysis
    - Eigenvalue problems and solutions
    - Natural modes of vibration
    - Steady-state response to harmonic excitations
    - Time response via modal analysis
    - Damping in vibrating systems
    - Gyroscopic effects
    - Use of MATLAB in analysis and simulation
- State equations and transfer function formulation
    - State equations and solution via eigenvector expansion and numerical integration
    - Transfer function formulation
    - Distributed transfer function method
- Distributed vibrating systems
    - Calculus of variations
    - Extended Hamilton's principles
    - One-dimensional continua (bars, strings, shafts and beams)
    - Eigenvalue problems
    - Modes of vibration
    - Eigenfunction expansion (modal analysis)

    - Vibration of membranes
    - Vibration of thin plates
- Distributed transfer function method
- Approximate methods for distributed systems
    - Rayleigh's quotient
    - Assumed modes method
    - Finite element method
- Applications
    - Combined distributed-lumped systems
    - Dynamic vibration absorption
    - Dynamics of structures carrying moving subsystems

## Course Schedule

| **Important Dates** | | | |
|---|---|---|---|
| | 2025/09/29 | Midterm Exam 1 (110 mins) | Online exam |
| | 2025/10/29 | Midterm Exam 2 (110 mins) | Online exam |
| | 2025/12/03 | Midterm Exam 3 (110 mins) | Online exam |
| | 2025/12/10 | Project report due (Wedn., by 11:59 pm) | Online submission |

| Week | Date | Materials Covered/Exams | HW/Project |
|---|---|---|---|
| 1 | 8/25 | Review of single-degree-of-freedom systems (AME420 course materials)<br>Textbook: Chapters 1 and 2 | |
| | 8/27 | Multi-degree-of-freedom (M-DOF) systems: governing equations by Newtonian approach<br>Textbook: Section 3.1 | HW 1 - 6 problems: **2.5, 2.14, 2.17, 3.1, 3.5, 3.6** |
| 2 | 9/1 | Labor Day – No class | |
| | 9/3 | M-DOF systems: Lagrange Equations<br>Textbook: Section 3.2 | |
| 3 | 9/8 | M-DOF systems: linearization, and more examples<br>Textbook: Sections 3.3-3.6 | HW 2 – 6 problems:<br>**3.8, 3.12, 3.13, 3.19, 3.22, 4.2** |
| | 9/10 | M-DOF systems: eigenvalue problems<br>Textbook: Sections 4.1-4.4 | |
| 4 | 9/15 | M-DOF systems: free vibration, modal analysis<br>Textbook: Sections 4.5-4.7 | HW3 – 6 problems:<br>**4.3, 4.4, 4.9, 4.13, 4.16, 22** |
| | 9/17 | M-DOF systems: modal analysis<br>Textbook: Sections 4.8-4.10 | |
| 5 | 9/22 | M-DOF systems: damped systems<br>Textbook: Sections 5.1-5.4 | HW4 – 6 problems:<br>**4.23, 4.25, 5.2, 5.5, 5.9, 5.14** |
| | 9/24 | M-DOF systems: general mechanical systems<br>Textbook: Sections 5.5-5.7 | Project assignment (due by December 10, in 2 ½ months) |
| 6 | 9/29 | Midterm Exam 1 – online | |
| | 10/1 | Calculus of variations | |

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| | | Textbook: Sections 6.1-6.3 | |
| 7 | 10/6 | Extended Hamilton's principle, 1-D continua<br>Textbook: Sections 6.4-6.5 | HW 5 – 6 problems:<br>**6.2, 6.9, 7.3, 7.4, 7.11, 7.12** |
| | 10/8 | 1-D distributed systems: governing equations<br>Textbook: Sections 7.1-7.4 | |
| 8 | 10/13 | Eigenvalue problems of 1-D continua<br>Textbook: Sections 8.1-8.4 | HW 6 – 5 problems:<br>**8.1, 8.5, 8.6, 8.9, 8.13** |
| | 10/15 | Orthogonality of eigensolutions, modal analysis<br>Textbook: Sections 8.5-8.6 | |
| 9 | 10/20 | Modal analysis of 1-D continua, damped 1-D continua, steady-state response<br>Textbook: Section 8.7-8.10 | HW 7 – 5 problems:<br>**8.20, 8.25, 8.26, 8.30, 8.33** |
| | 10/22 | Distributed transfer function method (DTFM)<br>Textbook: Section 10.1-10.3 | |
| 10 | 10/27 | DTFM: eigensolutions of 1-D continua, stepped systems<br>Textbook: Section 10.4-10.6 | HW8 – 3 problems:<br>**10.2, 10.6, 10.11** |
| | 10/29 | Midterm Exam 2 -- online | |
| 11 | 11/3 | Approximation methods: comparison and admissible functions, Rayleigh Ritz method<br>Textbook: Section 11.1-11.3 | |
| | 11/5 | Approximation: the assumed modes method<br>Textbook: Section 11.4 | HW 9 – 4 problems:<br>**11.1, 11.9, 11.16, 11.21** |
| 12 | 11/10 | Approximation: the finite element method, application – combined systems<br>Textbook: Sections 11.5 and 12.1 | |
| | 11/12 | Application: combined systems<br>Textbook: Section 12.2 | |
| 13 | 11/17 | Application: structures under moving subsystems<br>Textbook: Sections 12.3 | HW 10 – 3 problems:<br>**12.2, 12.6, 9.1** |
| | 11/19 | Two-dimensional continua: membranes<br>Textbook: Sections 9.1-9.2 | |
| 14 | 11/24 | Two-dimensional continua: plates<br>Textbook: Sections 9.3-9.4 | HW 10 due on 11/26 |
| | 11/26 | Thanksgiving Break – No class | |
| 15 | 12/1 | Two-dimensional continua: plates<br>Project tips | |
| | 12/3 | Midterm Exam 3 – online | Last class |
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| 16 | 12/10 | Project report due on Wedn. by 11:59 PM<br>online submission | |