ME1020 – MECHANICAL VIBRATIONS

2024-2025 Spring

(Modifications to this syllabus may be required during the semester. Any changes to the syllabus will be posted on the course website and announced in class)

Catalog Description and Objective

Vibrations in engineering systems are associated with noise and rapid wear of machine parts. The course introduces the foundations of vibration theory and its applications to the analysis and design of mechanical systems. Computer tools will be utilized by students to develop programs for the vibration analysis. (3 credit hours).

Prerequisites:

- ME 1014 Dynamic systems or equivalents

Lecture time/location: Wednesday 13:50 - 16:25 / room N209.

Textbook & References:

- D.J. Inman: Engineering Vibration, 4th Edition, Pearson Higher Ed., ISBN–9780273768449
- Additional references and supplementary materials will be posted on Blackboard.

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Office Hours: Tuesday 13:00 – 16:30 and Wednesday 09:00 – 11:30
For consultation outside office hours, please send an email to make an appointment. Note: please include the course name/number, your name and student number in the message. In the subject field of your email indicate the issue (and use your university email account).

Course Objectives:

- Introduce students to the modeling and analysis of vibrations in mechanical systems.
- Acquaint students with the common methods of suppressing vibrations in mechanical systems.
- Develop the students' skills in the utilization of computer tools to investigate the vibrations in mechanical systems.

Course Learning Outcomes:
After the successful completion of this course students should be able to:

- Model mechanical systems for vibration analysis.
- Evaluate the free and forced responses of single and multiple degree of freedom systems.

- Develop solutions to suppress the vibrations.
- Utilize computer tools to analyze mechanical vibrations.

This course contributes to the following ABET Criterion 3 outcomes:
(1) Identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
(2) Apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
(3) Communicate effectively with a range of audiences.
(7) Acquire and apply new knowledge as needed, using appropriate learning strategies.

Assessment Policy:

ACTIVITIES	PERCENTAGES
Quizzes, labs	20%
Project	25%
Exam 1	25%
Exam 2	30%

Grading Scale:

Letter	A	A-	B+	B	B-	C+	C	C-	D+	D	F
Percentage (%)	100~90	89~85	84~80	79~76	75~73	72~70	69~66	65~63	62~61	60	<60

Class Policies:

- Sichuan University attendance policy will be enforced. Attendance will be taken at the start and checked at the end of the class. Students who come to class more than 15 minutes late (without valid reasons) will be considered as absent. Students who leave class early (without valid reasons) will be considered absent. Students who sign the attendance for another student will be considered as absent and will be reported to the University as a misconduct. Students performing activities not associated with the course while in class (e.g., sleeping, watching video, playing games, doing other course assignments or personal work) will be considered absent.
- Students with 3 unexcused absences (including lateness or leaving class early) will receive zero for all quizzes, studios, laboratory exercises, and projects (i.e., only the midterm and final exams' marks will be considered towards their final grades).

- Students who missed more than a third of the classes (these absences included classes missed with and without approval and valid reasons) will lose the right to be assessed and will receive zero for the course. These students will NOT be allowed to take the makeup exam.
- All quizzes, laboratory exercises, project and exams have clearly stated submission requirements. No marks will be given if the submission requirements are not met. Late submissions will not be accepted. No makeup for quizzes, laboratory exercises, and project will be allowed.
- If a student cannot attend the midterm examination, the student must contact the instructor immediately with a valid reason. If the reason stated is consistent with University Policy, arrangements can be made for alternate assessments. Otherwise, the student will get zero for the midterm examination.
- If a student has a valid reason and cannot attend the final exam, the student must apply to the administration for a deferred examination.
- Challenge to the grading must be made within 7 days after the returned of the graded assessment item. No challenges to the grading will be entertained after the 7-day period.

Academic misconduct and non-academic misconduct will not be tolerated. All misconduct will be reported and dealt with by SCUPI.

Academic Misconduct:

All students in attendance at the Sichuan University are expected to be honorable and to observe standards of conduct appropriate to a community of scholars. The University expects from its students a higher standard of conduct than the minimum required to avoid discipline. Academic misconduct includes all acts of dishonesty in any academically related matter and any knowing or intentional help or attempt to help, or conspiracy to help, another student. The Academic Misconduct Disciplinary Policy will be followed in the event of academic misconduct.

Non-academic Misconduct:

All cell phones, and mobile phones are to be turned off and put out of sight during lectures (mobile phones and computers can be turned on during studios). All newspapers and other materials not related to the class are to be put away once class begins. Operating these devices and reading unrelated materials while in class is disrespectful to your instructor and fellow classmates. If you fail to abide by this rule, the instructor has the right to confiscate the device or materials and mark you as absent. If you have an emergency and need to have your phone turned on during class, ask your instructor for permission.

Tentative Course Schedule (changes will be announced):

Week	Topic	Description
1	Introduction • Chap. 1.1, 1.2	Course objectives, prerequisites, learning outcomes, schedule, and learning resources. Class policies including assessment, and grading. Course overview & importance of vibration analysis. Free vs. forced vibration. Vibration characteristics. Fourier series of Periodic motions. Simple harmonic motions. Representations and manipulate harmonic motions using trigonometry, rotating phasors, and complex algebra. Relationships between time & frequency domain representations.
2	Modelling of mechanical systems • Chap. 1.3, 1.4, 1.5, 1.9	Continuous vs. discrete mechanical systems & degree of freedom. Inertia, spring, & damper elements. Review of linear dynamic systems and mathematical models using ordinary differential equations. Modelling of mechanical systems using free-body-diagrams & Newton's laws. Modelling of mechanical systems using Lagrange's equation.
3	Free vibration of 1-DOF 2nd order mechanical systems • Chap. 1.6, 1.7, 1.8, 1.10, 4.7	Free responses of 1-DOF 2nd order systems: undamped, underdamped, critically damped, & overdamped cases. Comparison of free responses. Determination of damping ratio and natural frequency. Applications of 1-DOF 2nd order systems' free response vibration characteristics in engineering. Stability considerations. Free responses with Coulomb friction. Transient & steady state responses. Frequency response representation using amplitude ratios & phase shifts at different frequencies.
4	Harmonic excitation of 1-DOF 2nd order mechanical systems • Chap. 2.1, 2.2, 2.7	Time response of 1-DOF 2nd order system with and without damping to harmonic excitation. Steady state time response of 1-DOF 2nd order systems to harmonic excitation. Frequency response of 1-DOF 2nd order systems to harmonic excitation including concepts of bandwidth and resonance. Determination of mass, spring constant and damping coefficient from frequency responses. Equivalent Coulomb damping and equivalent damping models.
5	Base-excitation • Chap. 2.3, 2.4, 2.6	Introduction to base excitation due to displacement inputs. Determination of displacement transmissivity. phase shift, force transmitted and force transmissivity for base excitation. Relative motion and applications in accelerometer & vibrometer. Design of seismic instrument.

Week	Topic	Description
6	Rotating imbalance in mechanical systems • Chap. 2.5, 5.7	Introduction to rotating machines and rotating imbalance. Amplitude ratio and phase shift characteristics of systems with rotating imbalance. Force transmission and transmissivity due to rotating imbalance. Whirling. An example of design based on rotating imbalance.
7	Exam 1	Covers Chaps. 1 & 2
8	Vibration isolation • Chap. 5.1, 5.2	Introduction to noise & vibration. Vibration nomograph. Vibration isolation for fixed base and design chart. Vibration isolation for moving base. Some examples of vibration isolation with industry applications.
9	Free vibration of 2-DOF undamped mechanical systems • Chap. 4.1, 4.2, 4.4, 4.9	Revision of matrix algebra. Second order matrix form. Mathematical model of 2-DOF undamped mechanical vibrating system. Natural frequencies & eigenvectors. Computation of eigenvectors. Free response of 2-DOF undamped mechanical systems. Principal modes and beats. Free response of n-DOF undamped mechanical systems. Case of repeated natural frequencies. Conversion of second order matrix form to state variable equation.
10	Undamped vibration absorber • Chap. 4.1, 4.2, 5.3	Harmonic response of 2-DOF undamped systems. Introduction to undamped vibration absorber. Design of undamped vibration absorber. Practical absorber design. Steady state vibration of 2-DOF damped systems to harmonic excitation.
11	Modal analysis • Chap. 4.3, 4.4, 4.5, 4.6	Similarity transformation. Modal analysis. Proportional damping. Signal and modal data analysis. Analysis using modal damping.
12	Balancing rotating machines • Handouts	Balancing of rotating machines. Static balancing. Problem with static balanced machines. Dynamic balancing. Considerations in machine balancing. Examples of machine balancing. Overview of vibration suppression techniques.
13	Exam 2	Covers Chap. 1, 2, 3, 4, 5
14	General responses & Computer analysis Chap. 3.1, 3.2. 3.3, 3.4, 3.9	Principle of superposition. Impulse excitation. Arbitrary input. Convolution integral. Arbitrary periodic input. Laplace transform. Transfer function & block diagrams.
15	Applications Chap. 7.4, 7.7	Machine condition monitoring. Design of active suspension system. SIMULINK
16	Project	
17	Project presentation	