ROSE Master of Science

Civil Engineering for Mitigation of Risk from Natural Hazards

Dynamics of Structures

Lecturer: G. Scalet - P. Venini
Date: 28/09/2026 – 21/12/2026
Credits: 6 ECTS (CFU)

Course Description

A solid foundation in structural dynamics is essential for structural engineering students and graduates and serves as a critical prerequisite for advanced coursework in earthquake engineering, blast-resistant design, wind engineering, and random vibrations.
This core graduate-level course examines the vibration characteristics and dynamic response of structural systems subjected to transient and continuous excitations, including those generated by earthquakes, wind, impact, and blast loading.
Students should have a standard undergraduate background in rigid-body dynamics. Familiarity with fundamental engineering mathematic-specifically differential equations and basic numerical methods-is strongly recommended.

Topics

The topics covered during the course will be the following:

- Equation of motion for SDOF systems, its solution.
- Free vibration response, viscous damping, Response to harmonic excitation.
- Response to general excitation, response spectrum.
- Generalized SDOF systems.
- Numerical evaluation of dynamic response for SDOF systems.
- Equations of motion for MDOF systems, Static condensation.
- Natural frequencies and modes, Modal and spectral matrices.
- Orthogonality of modes, Normalisation of modes, Solution for undamped free vibration.
- Damping in structures, Constructing a damping matrix, Solution for damped free vibration.
- Modal response analysis for damped forced vibration, and for linear system subjected to earthquakes.
- Impulse response, Frequency response, Convolution in the time and frequency domains.
- Singular values and matrix norms.
- Response spectrum analysis, Distributed mass systems, Equivalent SDOF analysis.

Learning Outcomes

By the end of the course, students are expected to possess a clear understanding of:

- **Structural Systems**: Discrete single-degree-of-freedom (SDOF), multi-degree-of-freedom (MDOF), and continuous vibratory systems.

- **Dynamic Response**: Free and forced vibration behaviors of both discrete and continuous systems under deterministic loading.
- **Engineering Applications**: Practical implementation of dynamic response analysis in structural design.

Suggested reading material/Reference textbooks

In addition to specific papers and handouts indicated/delivered during classes, the following general textbooks are recommended:

- Chopra A. (2007), Dynamics of Structures, Prentice Hall, Third Edition.
- Clough R.W., Penzien J. (2003), Dynamics of structures, Computers & Structures Inc.

Assessment Methods

Homework assignments 30%
Final Exam 70%

Schedule

Classroom: see the calendar here

Note:

- **September 21:** no classes
- **September 24:** no classes (Graduation days)
- **Thursday 29 afternoon:** no classes
- **November 5:** no classes (inauguration of the academic year at UniPV)
- **December 7:** no classes (national holiday)
- **December 17:** no classes (Graduation days)
- **December 24:** no classes (national holiday)

Week		Time	Hours
1	Monday, 28 September	11-13	2
	Equation of motion for SDOF systems, its solution (I)		
	Giulia Scalet		
	Thursday, 1 October	9-11	2
	Equation of motion for SDOF systems, its solution (II) Free vibration response, viscous damping, Response to harmonic excitation (I)		
	Giulia Scalet		
	Thursday, 1 October	14-16	2
	Free vibration response, viscous damping, Response to harmonic excitation (II)		
	Giulia Scalet		
2	Monday, 5 October	11-13	2
	Tutorial on the modelling of SDOF systems and homework assignment		
	Giulia Scalet		
	Thursday, 8 October	9-11	2
	Response to general excitation, response spectrum (I)		
	Giulia Scalet		
	Thursday, 8 October	14-16	2
	Response to general excitation, response spectrum (II) Generalized SDOF systems (I)		
	Giulia Scalet		
3	Monday, 12 October	11-13	2
	Tutorial on response spectrum and homework assignment		
	Giulia Scalet		
	Thursday, 15 October	9-11	2
	Generalized SDOF systems (II) Numerical evaluation of dynamic response for SDOF systems (I)		
	Giulia Scalet		
	Thursday, 15 October	14-16	2
	Numerical evaluation of dynamic response for SDOF systems (II)		
	Giulia Scalet		
4	Monday, 19 October	11-13	2
	Numerical evaluation of dynamic response for SDOF systems (III)		
	Giulia Scalet		
	Thursday, 22 October	9-11	2
	Numerical evaluation of dynamic response for SDOF systems (IV) Tutorial on numerical solution of SDOF systems and homework assignment (I)		
	Giulia Scalet		

Week		Time	Hours
	Thursday, 22 October	**14-16**	2
	Tutorial on numerical solution of SDOF systems and homework assignment (II)		
	Giulia Scalet		
5	**Monday, 26 October**	**11-13**	2
	Tutorial on numerical solution of SDOF systems and homework assignment (III)		
	Giulia Scalet		
	Thursday, 29 October	**9-11**	**2**
	Tutorial on homework problems		
	Giulia Scalet		
6	**Monday, 2 November**	**11-13**	2
	Second-Order Equations of Motion for MDOF Systems Using Lagrangian Coordinates		
	Paolo Venini		
	Thursday, 5 November	**9-11**	2
	First-Order Equations of Motion in State-Space and Descriptor State-Space Forms		
	Paolo Venini		
	Thursday, 5 November	**14-16**	2
	Tutorial on First-Order and Second-Order Equations of Motion		
	Paolo Venini		
7	**Monday, 9 November**	**11-13**	2
	Modal Analysis of Discrete Systems, The Autonomous Case 1 - Eigenvalues, Eigenvectors, and Their Engineering Interpretation		
	Paolo Venini		
	Thursday, 12 November	**9-11**	2
	Modal Analysis of Discrete Systems, The Autonomous Case 2: Main Properties - Orthogonality, Modal Matrices, Modal Decomposition, and Eigenvalue Multiplicity		
	Paolo Venini		
	Thursday, 12 November	**14-16**	2
	Tutorial on Modal Analysis of Autonomous Systems and Homework Assignment IV		
	Paolo Venini		
8	**Monday, 16 November**	**11-13**	2
	Modal Analysis of Discrete Systems: The Forced Case 1 - Modal Coordinates, Modal Forces, Damping, Modal Decomposition, Single-Mode Solutions, and Mode Superposition		
	Paolo Venini		
	Thursday, 19 November	**9-11**	2
	Modal Analysis of Discrete Systems: The Forced Case 2 - Base Acceleration, Storey Forces, and Mass Participation		
	Paolo Venini		
	Thursday, 19 November	**14-16**	2
	Tutorial on Modal Analysis Forced Systems		
	Paolo Venini		
9	**Monday, 23 November**	**11-13**	2
	Modal Analysis of Continuous Systems 1: The Eigenvalue Problem, Orthogonality Properties, Longitudinal Vibration of Rods, and Flexural Vibration of Beams		
	Paolo Venini		

Week		Time	Hours
	Thursday, 26 November	**9-11**	2
	Modal Analysis of Continuous Systems 2: Analytical Solutions via Separation of Variables and Approximate Solutions via FEM		
	Paolo Venini		
	Thursday, 26 November	**14-16**	2
	Tutorial on Modal Analysis of Forced Discrete Systems and Continuous Systems and Homework Assignment V		
	Paolo Venini		
10	**Monday, 30 November**	**11-13**	2
	Numerical Implementation of Discrete and Continuous Dynamical Systems 1		
	Paolo Venini		
	Thursday, 3 December	**9-11**	2
	Numerical Implementation of Discrete and Continuous Dynamical Systems 2		
	Paolo Venini		
	Thursday, 3 December	**14-16**	2
	Numerical Implementation of Discrete and Continuous Dynamical Systems 3		
	Paolo Venini		
11	**Thursday, 10 December**	**9-11**	2
	Response of MDOF Dynamical Systems - The Output Equation, Time-Domain State-Space vs. Laplace-Domain Transfer-Function Matrix Form		
	Paolo Venini		
	Thursday, 10 December	**14-16**	2
	Response of MDOF Dynamical Systems - Quantifying the System Response: Matrix Norms and Singular Values vs. Spectral Values		
	Paolo Venini		
12	**Monday, 14 December**	**11-13**	2
	Tutorial on the Response of MDOF Dynamical Systems in State-Space and Transfer-Function Matrix Forms and Homework Assignment V		
	Paolo Venini		
13	**Monday, 21 December**	**11-13**	2
	Final Questions, Clarifications, and Conclusions		
	Paolo Venini		