Western University
Faculty of Engineering
Department of Civil and Environmental Engineering

CEE 9610 – Advanced Structural Dynamics

COURSE OUTLINE

DESCRIPTION

In this course, the student will be able to:

- Understand and derive the governing equations of motion of a single and multi-degree of freedom system.
- Perform free and forced vibration response of a dynamical system under general loading.
- Develop the ability to characterize random variables and stationary stochastic processes.
- Develop the ability to interpret and analyze random vibration data with the aid of auto-correlation function and power spectral density functions.
- Perform different system identification methods and analyze time-invariant linear dynamical systems.
- Develop the ability to perform vibration testing, including free vibration, forced vibration and ambient vibration testing to extract relevant system information of structures.

ENROLLMENT RESTRICTIONS

Enrollment in this course is restricted to graduate students in CEE, as well as any student that has obtained special permission to enroll in this course from the course instructor as well as the Graduate Chair (or equivalent) from the student's home program.

INSTRUCTOR CONTACT INFORMATION

Course instructor: Dr. Ayan Sadhu, PhD, P.Eng.
Email address: asadhu@uwo.ca
Office: TBD
Lecture hours: TBD
Office hours: TBD

COURSE FORMAT

Face-to-face

TOPICS

Topic #	Description	Learning Activities	Tentative timeline
1	**Background of Dynamics**		
	Lesson 1: • Overview of second-order differential equations and basics of matrix equations	• Lecture • Additional reading material in OWL.	Week 1

	• Degrees-of-freedom and free body diagram; • Concepts of equivalent stiffness	• Assignment 1 (background assignment)	
	Lesson 2: • Free vibration response of undamped and damped SDOF system • Determination of damping	• Lecture • Assignment 2	Week 2
	Lesson 3: • Forced vibration response of an undamped and damped system	• Lecture • Assignment 3	Week 3
	Lesson 4: • Forced vibration response under general loading • Simulation of the earthquake-induced response • Concepts of response spectrum and design spectrum	• Lecture • Assignment 4 • Lab (Smart Cities laboratory)	Week 4-5
2	**Multi-degree of freedom system**		
	Lesson 5: • Modal analysis • free and forced vibration response • Rayleigh damping • Spectrum analysis and modal combination rules	• Lecture • Assignment 5 • Lab (Smart Cities laboratory)	Week 6-9 (**Week 7**: reading week – no class)
3	**Random Vibration**		
	Lesson 6: • Introduction to probability and statistics • Random process and stationary process • Autocorrelation function and its properties	• Lecture	Week 10
	Lesson 7: • Power spectral density functions • Wideband and narrowband process • The response of a linear system subjected to stationary input	• Lecture • Assignment 6	Week 11
4	**System Identification**		
	Lesson 8: • State-space representation of a linear system • Discrete and continuous systems	• Lecture • Assignment 7 • Additional reading material in OWL.	Week 12

	Lesson 9: • Time and frequency domain methods • Experimental modal analysis • Free, forced and ambient vibration testing and structural condition assessment • Sensing and data acquisition systems	• Lecture • Lab (Smart Cities laboratory) • Additional reading material in OWL.	Week 13

SPECIFIC LEARNING OUTCOMES

Degree Level Expectation	Weight	Assessment Tools	Outcomes
Depth and breadth of knowledge	30%	• Assignments • Project • Examinations	• Understanding of advanced concepts and theories • Awareness of important current problems in the field of study • Understanding of computational and/or empirical methodologies to solve related problems
Research & scholarship	20%	• Project	• Ability to conduct a critical evaluation of current advancements in the field of specialization • Ability to conduct coherent and thorough analyses of complex problems using established techniques/principles and judgment
Application of knowledge	20%	• Assignments • Project • Examinations	• Ability to apply knowledge in a rational way to analyze a particular problem • Ability to use a coherent approach to design a particular engineering system using existing design tools
Professional capacity /autonomy	10%	• Project	• Awareness of academic integrity • Ability to implement established procedures and practices in the coursework • Defends own ideas and conclusions • Integrates reflection into his/her learning process
Communication skills	10%	• Project	• Ability to communicate (oral and/or written) ideas, issues, results and conclusions clearly and effectively
Awareness of limits of knowledge	10%	• Project	• Awareness of the need of assumptions in complex scientific analyses and their consequences

			• Understanding of the difference between theoretical and empirical approaches • Ability to acknowledge analytical limitations due to the complexity of practical problems

ASSESSMENTS

Assessment Type	Material Covered	Tentative Due Date	Weight
Homework Assignments (6-7)*	Topics 1-4	Check the OWL announcement and the PDF of the assignment	30%
Course project**	Topics 1-4	December 7	15%
Course project (oral examination)	Topics 1-4	December 7/8	10%
Final examination***	Topics 1-4	December 15	45%

****submit a paper copy***
*****Please check "Course Project" section below.***
******Please check "Final Examination" section below.***

Activities in which collaboration is permitted:

- None.

Activities in which students must work alone (collaboration is not permitted):

- Homework
- Course project
- Final examination

REQUIRED TEXTBOOK

None.

OPTIONAL COURSE READINGS

1. Rao, S (2017). Mechanical Vibration, 6th Edition, Pearson.
2. Chopra, A.K. (2006). Dynamics of Structures: Theory and Applications to Earthquake Engineering, 3rd Edition. Prentice Hall.
3. Humar, J.L. (2002). Dynamics of Structures, 2nd Edition. A. A. Bulkema Publishers.
4. Meirovitch, L. (2001). Fundamentals of Vibrations, International Edition. McGraw-Hill.
5. Clough, R.W. and Pensien, J. (1993). Dynamics of Structures, 2nd International Edition. McGraw-Hill.
6. Juang, J-N. (1994). Applied System Identification, Prentice Hall, New Jersey.
7. Newland, D. E. (1984). An Introduction to Random Vibrations, Spectral and Wavelet Analysis, Prentice Hall, Third Edition.
8. Farrar, C.R. and Worden, K. (2013). Structural Health Monitoring: A Machine Learning Perspective, First Edition, Wiley.
9. Chapman, S. J. (2022). Matlab Programming for Engineers, Sixth Edition, CENGAGE.

COURSE PROJECT
Individual projects are assigned to each student, which will be submitted in terms of a project report. It will be based on the topics discussed in the lectures and should involve programming using MATLAB. The project details and topics will be discussed in the class and posted in March.

FINAL EXAMINATION
A final examination will be held covering the entire course material. It will be a three-hour open-book examination. Note that access to Matlab will NOT be permitted during the examination.

COMPUTING
A full version of MATLAB can be downloaded for academic use only through the MATLAB portal for Western University: **https://www.mathworks.com/academia/tah-portal/western-university-964054.html**

STATEMENT ON THE USE OF GENERATIVE ARTIFICIAL INTELLIGENCE (AI)
The use of AI in the preparation of the project and assignments must be acknowledged in the submission. Please refer to the published Provisional Guidance for the Use of Generative AI in Graduate Studies at Western University.

CHEATING, PLAGIARISM/ACADEMIC OFFENCES
Academic integrity is an essential component of learning activities. Students must have a clear understanding of the course activities in which they are expected to work alone (and what working alone implies) and the activities in which they can collaborate or seek help; see information above and ask instructor for clarification if needed. Any unauthorized forms of help-seeking or collaboration will be considered an academic offense. University policy states that cheating is an academic offence. If you are caught cheating, there will be no second warning. Students must write their essays and assignments in their own words. Whenever students take an idea or a passage of text from another author, they must acknowledge their debt both by using quotation marks where appropriate and by proper referencing such as footnotes or citations. Plagiarism is a major academic offence. Academic offences are taken seriously and attended by academic penalties which may include expulsion from the program. Students are directed to read the appropriate policy, specifically, the definition of what constitutes a Scholastic Offence at the following website: https://www.uwo.ca/univsec/pdf/academic_policies/appeals/scholastic_discipline_grad.pdf

CONDUCT
Students are expected to follow proper etiquette to maintain an appropriate and respectful academic environment. Any student who, in the opinion of the instructor, is not appropriately participating in course activities and/or is not following the rules and responsibilities associated with the course activities, will be reported to the Associate Dean (Graduate) (after due warning has been given). On the recommendation of the Department concerned, and with the permission of the Associate Dean (Graduate), the student could be debarred from completing the assessment activities in the course as appropriate.

HEALTH/WELLNESS SERVICES
As part of a successful graduate student experience at Western, we encourage students to make their health and wellness a priority. Western provides several health and wellness related services

to help you achieve optimum health and engage in healthy living while pursuing your graduate degree. Information regarding health- and wellness-related services available to students may be found at http://www.health.uwo.ca/.

Students seeking help regarding mental health concerns are advised to speak to someone they feel comfortable confiding in, such as their faculty supervisor, their program director (graduate chair), or other relevant administrators in their unit. Faculty of Engineering has a Student Wellness Counsellor. To schedule an appointment with the counsellor, contact Kristen Edwards (khunt29@uwo.ca) via confidential email and you will be contacted by our intake office within 48 hours to schedule an appointment.

Students who are in emotional/mental distress should refer to Mental Health@Western: http://www.uwo.ca/uwocom/mentalhealth/ for a complete list of options about how to obtain help.

SICKNESS

Students should immediately consult with the Instructor (for a particular course) or Associate Chair (Graduate) (for a range of courses) if they have problems that could affect their performance. The student should seek advice from the Instructor or Associate Chair (Graduate) regarding how best to deal with the problem. Failure to notify the Instructor or the Associate Chair (Graduate) immediately (or as soon as possible thereafter) will have a negative effect on any appeal. Obtaining appropriate documentation (e.g., a note from the doctor) is valuable when asking for accommodation due to illness.

Students who are not able to meet certain academic responsibilities due to medical, compassionate or other legitimate reason(s), could request for academic consideration. The Graduate Academic Accommodation Policy and Procedure details are available at:
https://www.eng.uwo.ca/graduate/current-students/academic-support-and-accommodations/index.html

ACCESSIBLE EDUCATION WESTERN (AEW)

Western is committed to achieving barrier-free accessibility for all its members, including graduate students. As part of this commitment, Western provides a variety of services devoted to promoting, advocating, and accommodating persons with disabilities in their respective graduate program. Graduate students with disabilities (for example, chronic illnesses, mental health conditions, mobility impairments) are strongly encouraged to register with Accessible Education Western (AEW): http://academicsupport.uwo.ca/accessible_education/index.html

AEW is a confidential service designed to support graduate and undergraduate students through their academic program. With the appropriate documentation, the student will work with both AEW and their graduate programs (normally their Graduate Chair and/or Course instructor) to ensure that appropriate academic accommodations to program requirements are arranged. These accommodations include individual counselling, alternative formatted literature, accessible campus transportation, learning strategy instruction, writing exams and assistive technology instruction.