Western University
Faculty of Engineering
Department of Civil and Environmental Engineering

CEE 4415 – Structural Health Monitoring

COURSE OUTLINE 2026

DESCRIPTION

In this course, the student will be able to:

- Understand basic notions of structural health monitoring (SHM) and various sensing and data acquisition technologies for civil infrastructure.
- Learn advanced engineering mathematics to understand SHM data analytics.
- Develop the ability to simulate, acquire, and model various forms of SHM data.
- Develop the ability to analyze SHM data using various time-domain, frequency-domain, and time-frequency methods.
- Develop the ability to characterize structural conditions using machine learning-based pattern recognition.
- Gain hands-on learning experience of next-generation SHM technologies using the Smart Cities and Communities (SCC) laboratory.

ENROLLMENT RESTRICTIONS

Completion of the third year of either B.E.Sc. or B.Sc. in civil engineering and smart cities program.

INSTRUCTOR CONTACT INFORMATION

[redacted]

COURSE FORMAT

Face-to-face

TOPICS

Description	Learning activities	Timeline
1. Introduction to SHM		
Lesson 1.1: Notion and needs of SHM • Basic introduction to SHM • Background of sensing, actuation, and acquisition of SHM	• Lecture material	Week 1
Lesson 1.2: Advanced engineering mathematics in SHM data analytics • Differential equation, matrix decomposition, including eigenvalue decomposition and singular value decomposition.	• Lecture materials • SCC lab work • Assignment #1	Week 2
2. Overview of dynamical systems and structural vibration		
Lesson 2.1: Background of dynamical systems	• Lecture materials	Week 2-4

• SDOF systems • Free vibration response and damping estimation • Forced vibration response • Response under general loading	• Assignment #2	
Lesson 2.2: MDOF systems • Modal analysis • Free vibration analysis • Forced vibration response and modal identification	• Lecture materials • SCC lab work • Assignment #3	Week 4-5
3. Frequency-domain SHM methods		
• Basic statistics and autocorrelation function • Fourier series, Fourier transform, and discrete Fourier transform (DFT) • Power spectral density function (PSDF) • Frequency domain decomposition (FDD) method	• Lecture materials • Assignment #4	Week 6
4. Time-domain SHM methods		
• Time-series modelling and Kalman Filtering • State-space modeling • Stochastic subspace identification (SSI)	• Lecture materials • Assignment #5	Week 7-8
5. Time-frequency domain SHM methods		
• Short-time Fourier Transform (STFT) and spectrogram • Wavelet transform (WT) and wavelet packet transform (WPT) • Empirical mode decomposition (EMD) and decomposition of SHM data	• Lecture materials • Assignment #6	Week 9-10
6. Advanced concepts in SHM		
• Acoustic emission (AE) • Imaging, digital image correlation (DIC), and computer vision • Immersive sensing environments: Mixed Reality (MR), Augmented Reality (AR), and Virtual Reality (VR)	• Lecture materials • SCC lab work • Assignment #7	Week 11
7. Course review		
• General review of the entire course materials • Discussion about the final examination format	• Lecture materials • Course project • Final examination	Week 12

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	• Ability to apply knowledge in a rational way to analyze a particular problem

		• Project • Examinations	• 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 their learning process
Communication skills	10%	• Project	• Ability to communicate (oral and/or written) ideas, issues, results and conclusions clearly and effectively
Awareness of the limits of knowledge	10%	• Project	• Awareness of the need for 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
Seven homework assignments*	Topics 1-6	Check the announcement on the course website and the PDF of the assignment	40%
Course project**	Topics 1-6	TBD	15%
Final examination***	Topics 1-6	TBD	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 assignments
- Course project
- Final examination

REQUIRED TEXTBOOK

None.

OPTIONAL COURSE READINGS

1. Rao, S (2017). Mechanical Vibration, 6th Edition, Pearson.
   The PDF version of this textbook is freely available online through ResearchGate.
2. Humar, J.L. (2002). Dynamics of Structures, 2nd Edition. A. A. Bulkema Publishers.

The textbook costs approximately $260. Students are welcome to purchase second-hand or earlier editions of this textbook.

3. Juang, J-N. (1994). Applied System Identification, Prentice Hall, New Jersey.
   The textbook costs approximately $65. Students are welcome to purchase second-hand or earlier editions of this textbook.
4. Newland, D. E. (1984). An Introduction to Random Vibrations, Spectral and Wavelet Analysis, Prentice Hall, Third Edition.
   The textbook costs approximately $40. Students are welcome to purchase second-hand or earlier editions of this textbook.
5. Farrar, C.R. and Worden, K. (2013). Structural Health Monitoring: A Machine Learning Perspective, First Edition, Wiley.
   The textbook costs approximately $200. Students are welcome to purchase second-hand or earlier editions of this textbook.
6. Chapman, S. J. (2022). Matlab Programming for Engineers, Sixth Edition, CENGAGE.
   The textbook costs approximately $80. Students are welcome to purchase second-hand or earlier editions of this textbook.

COURSE PROJECT

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

FINAL EXAMINATION

A final examination will be held covering the entire course material. It will be a three-hour 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

All required papers may be subject to submission for textual similarity review to the commercial plagiarism-detection software under license to the University for the detection of plagiarism. All papers submitted for such checking will be included as source documents in the reference database for the purpose of detecting plagiarism of papers subsequently submitted to the system. Use of the service is subject to the licensing agreement, currently between The University of Western Ontario and Turnitin.com (http://www.turnitin.com).

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.