# CVEN9840

Structural Health Monitoring Fundamentals and Practices

Term 3, 2022

# Course Overview

## Staff Contact Details

### Convenors

| Name | Email | Availability | Location | Phone |
|---|---|---|---|---|
| Mehrisadat Makki Alamdari | m.makkialamdari@unsw.edu.au | Mon 14:00-16:00 and Tues 14:00-16:00 | Room CE714, Civil Engineering Building (H20) | 9385 5018 |

## School Contact Information

Engineering Student Support Services – The Nucleus - enrolment, progression checks, clash requests, course issues or program-related queries

Engineering Industrial Training – Industrial training questions

UNSW Study Abroad – study abroad student enquiries (for inbound students)

UNSW Exchange – student exchange enquiries (for inbound students)

UNSW Future Students – potential student enquiries e.g. admissions, fees, programs, credit transfer

### Phone

(+61 2) 9385 8500 – Nucleus Student Hub

(+61 2) 9385 7661 – Engineering Industrial Training

(+61 2) 9385 3179 – UNSW Study Abroad and UNSW Exchange (for inbound students)

# Course Details

## Units of Credit 6

## Summary of the Course

Structural health monitoring (SHM) refers to the process of design and implementing a condition monitoring and characterization strategy for engineering structures. Needs for optimization of maintenance costs, objective and science-based inspection practices, increase of safety, emergence of new and improved construction materials and methods, new developments in measurement, sensing, processing and monitoring, as well as recent technological developments in various branches of science and engineering led to creation of relatively new, interdisciplinary branch of engineering – Structural Health Monitoring. SHM examines the use of low-cost, long term monitoring systems to keep infrastructure under constant surveillance, ensuring structural integrity. It has received great deal of attention all over the world due to its significant impact on safety and longevity of the structures.

This subject provides an introduction and motivation of SHM with a systematic approach to SHM process. It introduces the topics with basic definitions of measurement and monitoring, various available and emerging monitoring technologies, data acquisition systems and instrumentation, passive and active sensing technologies. The course will cover the principal methods used for local non-destructive evaluation (NDE) and global vibration based SHM techniques. Overview of signal processing basics, feature extraction and a comprehensive list of comparative features will be addressed. Brief overview of structural dynamics will be presented. The students will be provided with hands-on experience in experimental and operational modal analysis, and will learn techniques for structural properties extraction from the measured data. Basics on data interpretation are presented. The subject will also introduce students to the concepts of statistical pattern recognition and machine learning with focus on some well-known supervised and un-supervised learning techniques.

## Course Aims

The topic of SHM is extremely relevant to the civil engineering profession as there is an ever-increasing demand to ensure the safety, and assess the state of health of existing structures. This subject will provide students with the tools and skills which can be implemented to develop sustainable maintenance and monitoring schemes which is critically important for civil engineering practice.

This subject is intended for postgraduate or senior undergraduate level students in CVEN. This subject cuts across the traditional subjects' boundaries and educate students with advanced problem-solving techniques. The aim is to fill the gap between the theoretical knowledge and its applications to civil engineering by providing enough insights into the relationship between the problems encountered in practice and the associated theory.

## Course Learning Outcomes

After successfully completing this course, you should be able to:

| Learning Outcome | EA Stage 1 Competencies |
|---|---|
| 1. Understand and implement fundamental concepts of SHM | PE1.1, PE1.2, PE1.3, PE1.4, PE1.5, PE1.6 |
| 2. Identify, formulate and solve engineering problems under | PE2.1, PE2.2, PE2.3, PE2.4 |

| Learning Outcome | EA Stage 1 Competencies |
|---|---|
| realistic constraints and conditions | |
| 3. Devise and implement proper analysis and modelling methods of SHM | PE2.1, PE2.2, PE2.3, PE2.4 |
| 4. Perform the theory of structural dynamics and non-destructive testing techniques | PE2.1, PE2.2, PE2.3, PE2.4 |
| 5. Develop analytical and independent critical thinking | PE3.3 |
| 6. Communicate effectively orally and in writing | PE3.2 |

## Teaching Strategies

Learning and teaching strategies in this course include research inspired, practice oriented and collaborative and project-based learning approaches through a mixture of lectures, workshops and assignments.

Lectures will cover the concepts and theories of SHM. Application of the theories to formulate guidelines in the analysis of practical engineering problems will be emphasized. The workshops provide students with the opportunity to discuss the lecture materials with lecturer and to solve the set exercise problems. In addition, students will be provided with some hands-on work, to set studies in context by conducting vibration measurement and NDE of small specimen in the classroom. The students will analyse and interpret the collected data according to the frameworks presented in the lectures.

Suggested approaches to learning in the course are listed below.

**Private Study:**

- Review lecture material and textbook
- List difficulties
- Preparation for the workshop and do set problems
- Reflect on class problems
- Study relevant references
- Download materials from Moodle
- Keep up with notices and find out marks via Moodle
- Join Moodle discussions of problems
- Work on assignment
- Prepare for quizzes

**Lectures:**

• Find out what you must learn

• Follow worked examples

• Hear announcements on course changes

**Workshops:**

- Be guided by the lecturer
- Practice solving set problems
- Identify and resolve difficulties in theory and problem-solving
- Ask questions

**Assessments:**

• Demonstrate your knowledge and skills

• Demonstrate higher understanding and problem solving

## Additional Course Information

Suggested approaches to learning in this course include:

- Regular participation in lectures. Review lecture and workshop material. Follow worked examples. Reflect on class problems.
- Weekly reading and recording of your learning.
- Appropriate preparation for workshop activities.
- Planning your time to achieve all assessment requirements (see assessment).
- Keep up with the notices via Moodle and UNSW email. It is your responsibility to check your UNSW email regularly. NOTE: Announcements made in emails are equally official as announcements made during lectures.
- We encourage you to work with your peers. A good way to learn the material is in small study groups. Such groups work best if members have attempted the problems individually before meeting as a group. A valued and honest collaboration occurs when, for example, you “get stuck” early on in attacking an exercise and go to your classmate with a relevant question. Your classmate then can learn from your question as well as help you.

# Assessment

The assessment of this course will be based on four assignments and a final exam. The final grade will be based on the sum of the scores from each of the assessment tasks. The lecturer reserves the right to adjust the final scores by scaling.

The purpose of the assignments is to expose you to a realistic problem, which requires you to apply what you have learned. Similar to engineering practice, this will require you to find additional information by asking, reading or discussing with your classmates, to critically evaluate your model and to formulate conclusions. Here, documentation is equally important as results. It is expected that you submit a report that is similar in scope, form, and style to what you would submit to a private or public client.

A mark of at least 40% in the final examination is required before the class work is included in the final mark.

***Penalties***

*Late submissions of the assignment will be penalised* ***at the rate of 5% of the maximum achievable mark per day*** *after the due time and date have expired.* ***Submissions that are more than 5 days late (unless special considerations have been granted) are not accepted and 0 marks are awarded.***

| Assessment task | Weight | Due Date | Course Learning Outcomes Assessed |
|---|---|---|---|
| 1. Assignment 1 | 10% | 27/09/2022 | 1, 6 |
| 2. Assignment 2 | 10% | 11/10/2022 | 1, 2, 3, 4, 5, 6 |
| 3. Assignment 3 | 15% | 01/11/2022 | 1, 2, 3, 4, 5, 6 |
| 4. Assignment 4 | 15% | 15/11/2022 | 1, 2, 3, 4, 5, 6 |
| 5. Final Exam | 50% | Exam Period | 1, 2, 3, 4, 5, 6 |

## Assessment 1: Assignment 1

**Due date:** 27/09/2022

*See assignment question uploaded on Moodle*

## Assessment 2: Assignment 2

**Due date:** 11/10/2022

*See assignment question uploaded on Moodle*

## Assessment 3: Assignment 3

**Due date:** 01/11/2022

*See assignment question uploaded on Moodle*

## Assessment 4: Assignment 4

**Due date:** 15/11/2022

*See assignment question uploaded on Moodle*

## Assessment 5: Final Exam

**Due date:** Exam Period

Entire course materials

**Hurdle requirement**

Example: A mark of at least 40% in the final examination is required before the class work is included in the final mark.

## Attendance Requirements

Students are strongly encouraged to attend all classes and review lecture recordings.

## Course Schedule

### Lecture

**Monday** **14:00 – 16:00 (In person, K-H20-101)**

**Tuesday** **14:00 – 16:00 (In person, K-H20-101)**

**Public holiday: no lecture in week 4 on 3rd of October (Labour Day)**

**Flexibility week: no lecture/workshop in week 6**

View class timetable

### Timetable

| Date | Type | Content |
|---|---|---|
| O-Week: 5 September - 9 September | | |
| Week 1: 12 September - 16 September | Lecture | **Structural Health Monitoring (SHM) Background and Motivation** |
| Week 2: 19 September - 23 September | Lecture | **Measurement and Sensing** |
| Week 3: 26 September - 30 September | Lecture | **Structural Dynamics Single Degree of Freedom (SDOF)** |
| Week 4: 3 October - 7 October | Lecture | **Public Holiday Labour Day Monday 3 October**<br><br>**Structural Dynamics Multi Degree of Freedom (MDOF)** |
| Week 5: 10 October - 14 October | Lecture | **Experimental Modal Analysis (EMA)** |
| Week 6: 17 October - 21 October | | **Flexibility week for all courses (non-teaching)** |
| Week 7: 24 October - 28 October | Lecture | **Experimental Modal Analysis (EMA) (Continued)** |
| Week 8: 31 October - 4 November | Lecture | **Vibration Based Damage Identification** |

| | | |
|---|---|---|
| Week 9: 7 November - 11 November | Lecture | **Statistical Learning** |
| Week 10: 14 November - 18 November | Lecture | **Non-Destructive Testing** |

# Resources

## Recommended Resources

Farrar, C.R. and Worden, K., 2012. *Structural health monitoring: a machine learning perspective*. John Wiley & Sons.

Chen, H.P. and Ni, Y.Q., 2018. Structural health monitoring of large civil engineering structures. Hoboken, NJ: Wiley Blackwell.

Placko, D. ed., 2013. *Fundamentals of instrumentation and measurement*. John Wiley & Sons.

Morris, A.S. and Langari, R., 2012. *Measurement and instrumentation: theory and application*. Academic Press.

Géradin, M. and Rixen, D.J., 2014. *Mechanical vibrations: theory and application to structural dynamics*. John Wiley & Sons.

Chopra, A.K., 2017. Dynamics of structures. theory and applications to. *Earthquake Engineering*.

Graham, K.S., 2000. Fundamentals of Mechanical Vibrations.

Ewins, D.J., 2009. *Modal testing: theory, practice and application*. John Wiley & Sons.

Fu, Z.F. and He, J., 2001. *Modal analysis*. Elsevier.

Duda, R.O., Hart, P.E. and Stork, D.G., 2012. *Pattern classification*. John Wiley & Sons.

Bishop, C.M., 2006. *Pattern recognition and machine learning*. springer.

Murphy, K.P., 2012. *Machine learning: a probabilistic perspective*. MIT press.

Mix, P.E., 2005. *Introduction to nondestructive testing: a training guide*. John Wiley & Sons.

## Submission of Assessment Tasks

Please refer to the Moodle page of the course for further guidance on assessment submission.

**UNSW has a standard late submission penalty of:**

- 5% per day, for all assessments where a penalty applies, capped at five days (120 hours), after which a student cannot submit an assessment, and no permitted variation.

## Academic Honesty and Plagiarism

Beware! An assignment that includes plagiarised material will receive a 0% Fail, and students who plagiarise may fail the course. Students who plagiarise are also liable to disciplinary action, including exclusion from enrolment.

Plagiarism is the use of another person's work or ideas as if they were your own. When it is necessary or desirable to use other people's material you should adequately acknowledge whose words or ideas they are and where you found them (giving the complete reference details, including page number(s)). The Learning Centre provides further information on what constitutes Plagiarism at:

https://student.unsw.edu.au/plagiarism

# Academic Information

**Final Examinations:**

Final exams in T3 2022 will be held online between 25th November - 8th December 2022 inclusive, and supplementary exams between 9th - 13th January 2023 inclusive. You are required to be available on these dates. Please do not to make any personal or travel arrangements during this period.

**ACADEMIC ADVICE**

- Key Staff to Contact for Academic Advice (log in with your zID and password): https://intranet.civeng.unsw.edu.au/key-staff-to-contact-during-your-studies-at-unsw
- Key UNSW Dates - eg. Census Date, exam dates, last day to drop a course without academic/financial liability etc.
- CVEN Student Intranet (log in with your zID and password): https://intranet.civeng.unsw.edu.au/student-intranet
- Student Life at CVEN, including Student Societies: https://www.unsw.edu.au/engineering/civil-and-environmental-engineering/student-life
- Special Consideration: https://student.unsw.edu.au/special-consideration
- General and Program-Specific Questions: The Nucleus: Student Hub
- Book an Academic Advising session: https://app.acuityscheduling.com/schedule.php?owner=19024765

# Disclaimer

*This course outline sets out description of classes at the date the Course Outline is published. The nature of classes may change during the Term after the Course Outline is published. Moodle should be consulted for the up to date class descriptions. If there is any inconsistency in the description of activities between the University timetable and the Course Outline (as updated in Moodle), the description in the Course Outline/Moodle applies.*

## Image Credit

Mike Gal.

## CRICOS

CRICOS Provider Code: 00098G

## Acknowledgement of Country

We acknowledge the Bedegal people who are the traditional custodians of the lands on which UNSW Kensington campus is located.

## Appendix: Engineers Australia (EA) Professional Engineer Competency Standard

| **Program Intended Learning Outcomes** | |
|---|---|
| Knowledge and skill base | |
| PE1.1 Comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline | ✓ |
| PE1.2 Conceptual understanding of the mathematics, numerical analysis, statistics, and computer and information sciences which underpin the engineering discipline | ✓ |
| PE1.3 In-depth understanding of specialist bodies of knowledge within the engineering discipline | ✓ |
| PE1.4 Discernment of knowledge development and research directions within the engineering discipline | ✓ |
| PE1.5 Knowledge of engineering design practice and contextual factors impacting the engineering discipline | ✓ |
| PE1.6 Understanding of the scope, principles, norms, accountabilities and bounds of sustainable engineering practice in the specific discipline | ✓ |
| Engineering application ability | |
| PE2.1 Application of established engineering methods to complex engineering problem solving | ✓ |
| PE2.2 Fluent application of engineering techniques, tools and resources | ✓ |
| PE2.3 Application of systematic engineering synthesis and design processes | ✓ |
| PE2.4 Application of systematic approaches to the conduct and management of engineering projects | ✓ |
| Professional and personal attributes | |
| PE3.1 Ethical conduct and professional accountability | |
| PE3.2 Effective oral and written communication in professional and lay domains | ✓ |
| PE3.3 Creative, innovative and pro-active demeanour | ✓ |
| PE3.4 Professional use and management of information | |
| PE3.5 Orderly management of self, and professional conduct | |
| PE3.6 Effective team membership and team leadership | |