School of Civil and Environmental Engineering

Term 3, 2020

CVEN4308

STRUCTURAL DYNAMICS

COURSE DETAILS

Units of Credit	**6**	
Contact hours	5 hours per week	
Lecture	Monday, 15:00 – 18:00	online
Workshop	Tuesday, 12:00 – 14:00	online
	Tuesday, 14:00 – 16:00	online
	Tuesday, 16:00 – 18:00	online
	Thursday, 14:00 – 16:00	online
	Thursday, 16:00 – 18:00	online
Course Coordinator and Lecturer	Dr Sascha Eisenträger email: s.eisentraeger@unsw.edu.au office: Civil Engineering Building (H20), Level 6, Room CE614	

INFORMATION ABOUT THE COURSE

The aim of this course is to introduce students to the concepts and techniques involved in structural dynamics and their practical applications in structural engineering. The course begins with an introduction of the dynamics of simple structures and then develops the fundamental knowledge of vibration analysis of multi-degree-of-freedom structures and continuous structures. Students will develop an understanding of the nature of dynamic loads produced by various sources including earthquakes and acquire the ability to assess the response of civil engineering structures to such loads. The material covered in this course is essential to the analysis and design of large-scale structures such as multi-story buildings, towers and long-span bridges that are susceptible to vibration. Much of the knowledge acquired in this subject is also applicable to dynamic problems in other areas such as geotechnical engineering, mechanical engineering and material science.

The flow chart in Figure 1 shows diagrammatically how this course relates to other courses in the Civil Engineering program.

This course will also provide you with opportunities to develop the following generic graduate attributes:

- the capacity for analytical and independent critical thinking;
- skills related to lifelong learning, such as self-reflection (ability to apply theory to practice in familiar and unfamiliar situations).

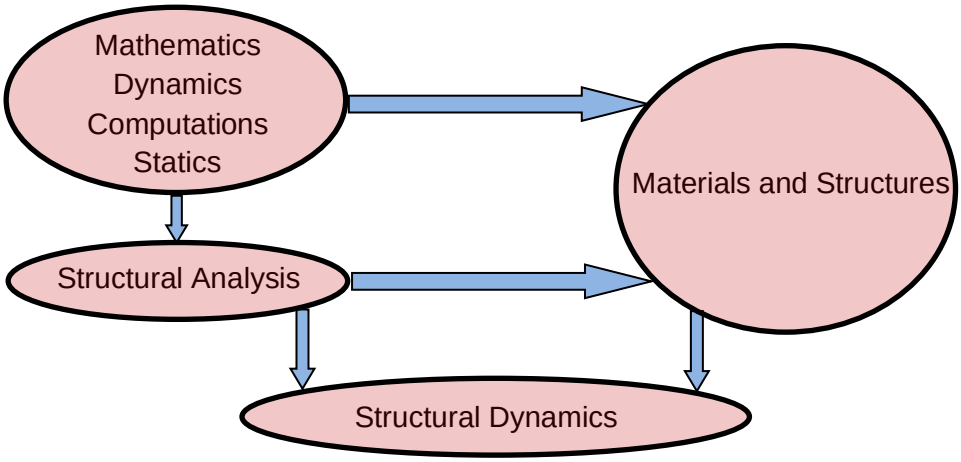

Figure 1. How this course relates to other courses in Civil Engineering.

HANDBOOK DESCRIPTION

Fundamentals of structural dynamic analysis for discrete and continuous structures; free and forced vibration of single and multiple-degrees-of-freedom systems; normal modal analysis; transient dynamic analysis by numerical integration; response spectrum; introduction to nonlinear dynamic analysis of structures; earthquake excitation: definitions and effects on structures; design of structures to resist dynamic loads.

https://www.handbook.unsw.edu.au/undergraduate/courses/2020/CVEN4308/

OBJECTIVES

The objective of this course is to enable students to gain a thorough understanding of the nature of dynamic loads and the key factors influencing the dynamic behaviour of structures. The course will provide you with an appreciation of the fundamental concepts of structural dynamics and earthquake engineering to be used in the design of structures against dynamic action.

These objectives contribute to the achievement of civil and environmental program outcomes in the following way:

- By studying the theoretical background concepts of structural dynamics and their application to realistic structural problems you will engage in depth with disciplinary knowledge in structural engineering.
- By applying the theoretical concepts learned to defined and open-ended class problems you will develop a capacity for analytical and critical thinking and for creative problem solving.
- By working on an assignment that requires you to find information beyond what was conveyed in the classroom you will engage in independent and reflective learning.
- By documenting your assignment work in a standard that would be expected in a real consultancy environment you will acquire skills for effective communication as well as collaborative and multi-disciplinary work.
- The assessment strategies used in this course will assist in achieving these objectives. Assessment consists of a mix of short pre-class quizzes, which encourage you to revise the theoretical background material learned in a timely and effective manner, comprehensive in-class quizzes that test your understanding of the fundamental concepts and your ability to apply learned strategies to

relevant problems, a major assignment, that challenges your engineering abilities and a final exam. Further details are provided in the Assessment section.

TEACHING STRATEGIES

This subject consists of a mixture of lectures, workshops, and laboratory sessions.

Lectures will cover the basic theories of structural dynamics and its applications to structural engineering. Application of the theories to formulate guidelines in the analysis of practical engineering problems will be emphasized.

The workshops provide you with the opportunity to discuss the lecture material with your demonstrators and to solve the set exercise problems. To understand the subject matter well, it is essential to attend the workshops and solve the set problems by yourself.

For each hour of contact it is expected that you will put in at least 1.5 hours of private study. You are recommended to review the lecture and workshop material weekly.

The teaching/learning activities are summarized in the following table:

Private Study	• Review lecture material and textbook • Do set problems and assignments • Join Moodle discussions of problems • Reflect on class problems and assignments • Download materials from Moodle • Keep up with notices and find out marks via Moodle
Lectures	• Find out what you must learn • See methods that are not in the textbook • Follow worked examples • Hear announcements on course changes
Workshops	• Be guided by Demonstrators • Practice solving set problems • Ask questions
Assessments	• Demonstrate your knowledge and skills • Demonstrate higher understanding and problem solving
Laboratory Work	• Hands-on work, to set studies in context

Suggested approaches to learning in this course include:

- Regular participation in lectures and workshops. Review lecture and workshop material. Follow worked examples. Reflect on class problems and quizzes.
- 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.

EXPECTED LEARNING OUTCOMES

This course is designed to address the learning outcomes below and the corresponding Engineers Australia Stage 1 Competency Standards for Professional Engineers as shown. The full list of Stage 1 Competency Standards may be found in Appendix A.

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

Learning Outcome		EA Stage 1 Competencies
1.	*Understand and apply the fundamental concepts of system dynamics with specific focus and application to civil/structural engineering.*	*PE1.1, PE1.2*
2.	*Identify and specify various types of dynamic loading for structural analysis.*	*PE1.3*
3.	*Apply the laws of dynamics to establish simple and realistic mathematical models of engineering structures.*	*PE1.2, PE2.1*
4.	*Analyse the dynamic response to a dynamic load and other important parameters for structural design.*	*PE2.1, PE2.3*
5.	*Evaluate the dynamic susceptibility of structures and the limitations of modelling techniques.*	*PE1.3, PE2.2, PE2.3, PE3.3*
6.	*Apply dynamic analysis methods to practical problems in structural engineering and other disciplines.*	*PE2.1, PE2.2, PE2.4*
7.	*Demonstrate collaborative skills by working with other students in TEAMS*	*PE3.5, PE3.6*

For each hour of contact it is expected that you will put in at least 1.5 hours of private study.

While the fundamental concepts and theoretical background of structural dynamics will be presented and discussed by the teacher during the lectures, it is what **YOU** do with it that makes you achieve these outcomes. Your active participation and engagement in workshops, homework exercises and open-ended problems determines to a great extent what you learn.

COURSE PROGRAM

A table of lectures and workshops or practical class topics for each week, indicating the name of lecturer involved (where multiple lecturers teaching in course), online activities, such as discussion forums, and relevant readings from textbook and other reference material identified for the course.

Term 3 2020

Date	Topic	Lecture Content	Demonstration Content
14/09/2020 (Week 1)	**Introduction** **Single-Degree-of-Freedom (SDOF) Systems** **Free Vibration of SDOF Systems**	Introduction; SDOF Systems, Force-Displacement Relationship, Damping Force, Equation of Motion, Mass- Spring-Damper System; Undamped and Damped Free Vibration	Various solved examples on SDOF Systems
21/09/2020 (Week 2)	**Free Vibration of SDOF Systems (continued)** **Harmonic Vibration of SDOF Systems**	Undamped and Damped Free Vibration; Harmonic Vibration of Undamped Systems, Harmonic Vibration of Damped Systems, Response to Vibration Generator, Natural Frequency and Damping from Harmonic Tests, Force Transmission and Vibration Isolation, Response to Ground Motion & Vibration Isolation	Various solved examples on Undamped and Damped Free Vibration; Various solved examples on Response of SDOF Systems to Harmonic Excitation
28/09/2020 (Week 3)	**Response to Periodic, Arbitrary, Step & Pulse Excitations of SDOF Systems** **Numerical Methods for Dynamic Response Evaluation**	Response to Unit Impulse, Response to Arbitrary Force, Response to Step & Ramp Forces; Time Stepping Methods, Central Difference Method, Newmark's Method, Stability and Computational Error	Various solved examples on Response to Periodic, Arbitrary, Step & Pulse Excitations; Various solved examples on Numerical Methods for Dynamic Response Evaluation
06/10/2020 (Week 4)	**Quiz 1**	***Public holiday Monday 5th Oct***	

12/10/2020 (Week 5)	**Multi-Degree-of-Freedom (MDOF) Systems** **Free Vibration Analysis of MDOF Systems**	Simple MDOF System, General Approach for Linear MDOF System; Natural Vibration Frequencies and Modes, Modal and Spectral Matrices, Orthogonality and Normalisation of Modes, Solution Methods of Eigenvalue Problem, Rayleigh's Quotient, Inverse Vector Iteration Method, Modal Expansion of Displacements, Free Vibration Response of Undamped and Damped MDOF Systems;	Various solved examples on Free Vibration Response of MDOF Systems
19/10/2020 (Week 6)		***Flexibility week for all courses (non-teaching)***	
26/10/2020 (Week 7)	**Modal Analysis** **Generalised SDOF Systems & Rayleigh's Method**	Modal Equations for Undamped and Damped Systems; System with Distributed Mass and Elasticity, Natural Vibration Frequency by Rayleigh's Method, Selection of Shape Function	Various solved examples on Modal Analysis; Various solved examples on Generalised SDOF Systems and Rayleigh's Method
02/11/2020 (Week 8)	**Quiz 2** **Earthquake Response of Linear Systems (SDOF)**	Earthquake Excitation, SDOF Equation of Motion, Response History, Response Spectrum Concept, Deformation, Pseudo-Velocity Pseudo-Acceleration Response Spectrum, Response Spectrum Characteristics, Elastic Design Spectrum, Elastic Design Spectrum vs Response Spectrum	Various solved examples on the Earthquake Response of Linear SDOF Systems
09/11/2020 (Week 9)	**Earthquake Response of Linear Systems (MDOF) Introduction to Wind Loading**	MDOF Equation of Motion, Response Spectrum Analysis, Modal Combination Rules; Wind-induced vibrations, random vibration/spectral approach	Various solved examples on the Earthquake Response of Linear MDOF Systems

16/11/2020 (Week 10)	**Structural Dynamics in the Finite Element Method**	Introduction to finite element analysis of structural dynamics by using commercial software: modelling issues, natural frequencies and mode shapes, response in frequency and time-domain	Examples of dynamic finite element simulations
	Assignment Submission **Revision**	**Revision**	**Revision**

ASSESSMENT

The assessment of this course will be based on two comprehensive quizzes, one assignment 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.

Two in-class quizzes are scheduled for Weeks 4 and 8, respectively. They will be online and open book. The duration of the quizzes is 60 minutes. The quizzes will be held under exam conditions. The purpose of the quizzes is to test your understanding of the fundamental concepts and your ability to apply learned strategies to relevant problems.

One assignment is to be submitted in Week 10. The purpose of the assignment is to expose you to a realistic structural dynamics 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 who has commissioned you with the dynamic analysis.

A mark of at least 40% in the final examination is required before the class work is included in the final mark. The formal exam scripts will not be returned.

Students who perform poorly in the in-class quizzes and workshops are recommended to discuss progress with the lecturer during the semester.

Details of each assessment component, the marks assigned to it, the criteria by which marks will be assigned, and the dates of submission are set out below.

Supplementary Examinations for Term 3 2020 will be held on Monday 11th January – Friday 15th January 2021 (inclusive) should you be required to sit one. You are required to be available during these dates. Please do not to make any personal or travel arrangements during this period.

PENALTIES

Late submissions of the assignment will be penalised at the rate of 25% of the maximum achievable mark per day after the due time and date have expired. Submissions that are more than 4 days late (unless special considerations have been granted) are not accepted and 0 marks are awarded.

Late submissions of the quiz paper will be penalised by 25% of the maximum achievable mark per 5min and are not accepted after 15+ min past the due date and time.

ASSESSMENT OVERVIEW

Item	Length	Weighting	Learning outcomes assessed	Assessment Criteria	Due date and submission requirements	Deadline for absolute fail	Marks returned
1.Quizzes							
Quiz 1	45 min	10%		Application of taught concepts on SDOF systems	Week 4	Week 4	Week 4
Quiz 2	45 min	10%		Application of taught concepts on MDOF systems	Week 8	Week 8	Week 8
2. Assignment							
Assignment	7 days	20%		Application of taught concepts on SDOF and MDOF systems, and earthquake response	Week 10	Week 11	Week 11
4. Final Exam	2 hours	60%		Entire course content	TBA	TBA	TBA

RELEVANT RESOURCES

Textbook (recommended):
Chopra, A. K. Dynamics of Structures, 4th ed.: Prentice-Hall 2015.
Available online from UNSW Library and in print at Main Library Level 7 (624.1762/92) and other locations.

Recommended Reading:

1. Clough, R. W. and Penzien, J. Dynamics of Structures, 2nd ed.: McGraw-Hill 1993.
   Available at Main Library Level 7 (P 624.171/112 A)
2. Bolton, A. *Structural Dynamics in Practice: a Guide for Professional Engineers*, McGraw-Hill 1994.
   Available at Main Library Level 7 (P 624.171/212)
3. Rao, S. S. Mechanical Vibration, SI ed: Prentice-Hall 2011.
   Available at Main Library Level 7 (620.3/143 AC)
4. Bachmann H., Amman W.J., *Vibrations in structures: induced by man and machines,* Zurich, Switzerland : IABSE-AIPC-IVBH, 1987
   Available at Main Library Level 7 (P 624.176/55)
5. Humar, J. L. *Dynamics of Structures*, 3rd edition.: CRC Press/Balkema 2012
   Available at Main Library Level 7 (624.171/194 A)

Lecture notes, workshop problems and solutions, lecture videos and selected previous exam questions will be made available on **Moodle**.

DATES TO NOTE

Refer to MyUNSW for Important Dates available at:

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

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 ADVICE

For information about:

- Notes on assessments and plagiarism;
- Special Considerations: student.unsw.edu.au/special-consideration;
- General and Program-specific questions: The Nucleus: Student Hub
- Year Managers and Grievance Officer of Teaching and Learning Committee, and
- CEVSOC/SURVSOC/CEPCA

Refer to Academic Advice on the School website available at:

https://www.engineering.unsw.edu.au/civil-engineering/student-resources/policies-procedures-and-forms/academic-advice

Appendix A: Engineers Australia (EA) Competencies

Stage 1 Competencies for Professional Engineers

	Program Intended Learning Outcomes
PE1: Knowledge and Skill Base	PE1.1 Comprehensive, theory-based understanding of underpinning fundamentals
	PE1.2 Conceptual understanding of underpinning maths, analysis, statistics, computing
	PE1.3 In-depth understanding of specialist bodies of knowledge
	PE1.4 Discernment of knowledge development and research directions
	PE1.5 Knowledge of engineering design practice
	PE1.6 Understanding of scope, principles, norms, accountabilities of sustainable engineering practice
PE2: Engineering Application Ability	PE2.1 Application of established engineering methods to complex 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
PE3: Professional and Personal Attributes	PE3.1 Ethical conduct and professional accountability
	PE3.2 Effective oral and written communication (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