ENG ME 515: Vibration of Complex Mechanical Systems

Instructor

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Meeting Time and Place

Tuesdays and Thursdays, 4–6pm, PHO 210

Description

Vibrational analysis is an essential part of the design process for engineered systems from skyscrapers to micro chips, and from spacecraft to lawnmowers. Understanding the vibrational response of mechanical systems is critical to ensuring that they operate safely in the face of real-world disturbances. This course provides an introduction to the key topics in the study of linear vibration, taught at a graduate level of mathematical sophistication. The course will cover free and forced vibration of one degree of freedom systems, including Fourier analysis, Laplace transforms, transfer functions, frequency response, impulse response and convolution, and stability. It will also cover free and forced vibration of multi-degree of freedom systems, including Lagrangian mechanics, matrix formulations of equations of motion, eigenvalue problems and modal analysis, as well as approximate methods for the determination of natural frequencies and mode shapes such as Dunkerley's formula, Rayleigh's method, and Holzer's method. Finally, passive and active control of vibration, and an introduction to vibration in continuous media will be covered as time permits.

Prerequisites

All students should have taken ME 302 (Engineering Mechanics), ME 307 or ME 309 (Structural Mechanics), as well as the standard math sequence. Familiarity with Matlab will be helpful.

Structure and Expectations

The course will be have four main components: lectures, problem sets, exams, and a project.

Lectures Students will be expected to attend lectures and to have read the assigned reading prior to the lecture. Student participation will be encouraged in the lectures.

Problem sets Problem sets will be assigned approximately every 1.5 weeks. You are welcome to discuss the problems with your fellow students, but the solutions that you hand in should contain your *own original work*. Copied solutions are not acceptable. Make your solutions neat, complete, and legible. Problem sets should be turned in to the Mechanical Engineering front office by 5pm on date they are due. Extensions will only be considered under exceptional circumstances.

Exams We will have one midterm covering the first half of the course, an in-class final (not during finals week) covering the whole course, as well as occasional short quizzes throughout the semester. If you cannot be present for an exam, please let me know as early as possible to arrange a make-up exam.

Project There will be a significant project component to this class involving three steps. First, students will conduct a literature review in a research area relevant to the class. Second, students will propose a project based on their literature review. Finally, students will carry out the research project, producing a written research report as well as a presentation for the class.

Grading

The final course grade will be assigned according to the following weighting:

Problem sets		30%
Quizzes		10%
Midterm		15%
Final		15%
Project		30%
Literature review	5%	
Proposal	5%	
Final report/presentation	20%	

Course Website

All course materials will be disseminated on the blackboard course website. A link to blackboard can be found at `http://www.bu.edu/students/`.

Drop and Withdrawal Dates

The last day to *drop* the class (without a 'W' appearing on your transcript) is 2/21/2013.
The last day to *withdraw* from the class (with a 'W' appearing on your transcript) is 3/29/2013.

Textbooks

Required:
S. S. Rao, *Mechanical Vibrations*, 5th Edition, Prentice Hall/Pearson, 2011.

Optional:
D. J. Inman, *Engineering Vibration*, 3rd Edition, Prentice Hall/Pearson, 2007.
B. H. Tongue, *Principles of Vibration*, 2nd Edition, Oxford University Press, 2001.
J. H. Ginsberg, *Mechanical and Structural Vibrations: Theory and Applications*, 1st Edition, Wiley, 2001.
J. P. Den Hartog, *Mechanical Vibrations*, 3rd Edition, Crastre Press, 2008.

Planned Schedule

Date	Topic	Reading	Assignments
1/17 R	Introduction, linear ODEs, masses, springs, dampers	Chpt 1.1–1.9	
1/22 T	Harmonic motion, complex numbers, Fourier analysis	Chpt 1.10–1.13	PS 1 out
1/24 R	Free single degree of freedom vibration	Chpt 2.1–2.6	
1/29 T	Laplace transform, characteristic roots, root locus	Chpt 2.6–2.12	
1/31 R	Harmonically forced single degree of freedom	Chpt 3.1–3.11	PS 1 due, PS 2 out
2/5 T	Laplace transform and transfer functions	Chpt 3.12–3.13	
2/7 R	Fourier transform, frequency response, Bode plots	Chpt 3.14–3.15	
2/12 T	Vibration under general periodic forcing	Chpt 4.1–4.3	PS 2 due, PS 3 out
2/14 R	Impulse response and convolution	Chpt 4.4–4.6	
2/19 T	Laplace transform, step response	Chpt 4.7–4.10	
2/21 R	Two degree of freedom systems	Chpt 5.1–5.5	PS 3 due, PS 4 out
2/26 T	two degree of freedom transfer functions	Chpt 5.9–5.12	
2/28 R	Multi-degree of freedom systems, matrix formulation	Chpt 6.1–6.5	
3/5 T	Lagrangian mechanics	Chpt 6.6–6.8	PS 4 due
3/7 R	Midterm		
3/12 T	Spring break		
3/14 R	Spring break		
3/19 T	Eigenvalue problem and modal analysis	Chpt 6.9–6.11	PS 5 out
3/21 R	Free multi-degree of freedom vibration	Chpt 6.11–6.13	
3/26 T	Forced muti-degree of freedom vibration	Chpt 6.14–6.17	
3/28 R	Dunkerley, Rayleigh, Holzer methods	Chpt 7.1– 7.4	PS 5 due, PS 6 out
4/2 T	Matrix iteration, Jacobi's method, Choleski decomp.	Chpt 7.5–7.8	
4/4 R	Passive vibration control	Chpt 9.7-9.12	Lit review due
4/9 T	Active vibration control, feedback	Handout	PS 6 due, PS 7 out
4/11 R	Vibration of continuous media, strings, bars, beams	Chpt 8.1–8.5	Proposal due
4/16 T	Vibration of continuous media, membranes	Chapt 8.6–8.9	
4/18 R	No class, Monday class schedule		PS 7 due
4/23 T	Intro to finite element methods	Chpt 12	
4/25 R	Final		
4/30 T	Project presentations		
5/2 R	Project presentations		Project reports due