Dalhousie University
Department of Mechanical Engineering

MECH 4500 Vibrations (3-2)
Winter Term 2004

Professor: Dale Retallack, Ph.D., P.Eng.

Lectures: Tues & Thurs, 11:35 am – 12:55 pm, B 311

Tutorial/Lab: Wed, 3:35 – 5:25 pm, D 413

Text: Inman, **Engineering Vibration, Second Edition**, Prentice Hall, 2001,
ISBN 0-13-726142-X

Course Content

[Paraphrased from the Calendar]

Single and multiple degree-of-freedom lumped-parameter systems are examined in free vibration and in harmonically-excited vibration. Analytical as well as numerical solutions are covered. Vibration control in industrial applications is emphasized, and the effects of whole-body vibrations on humans are treated as a safety issue. Vibrations of continuous systems such as beams and shafts are introduced. Laboratory experiments deal with vibrations of lumped-parameter physical systems as well as vibrations of rotating machinery.

Objectives of the Course

Virtually all mechanical engineers will run into vibrations problems in their careers. Some will run into such problems only occasionally, while others will have to deal with them on a day-to-day basis. Designers have to be aware of the danger of designing vibrations problems into their products ; steps must be taken to avoid such costly mistakes. Sometimes we 'inherit' vibrations problems because other engineers did not take the necessary precautions in their designs, and we are faced with retrofits to correct their mistakes --- potentially a much more expensive approach than 'designing away' the problems right from the beginning.

The purpose of this course is to give students enough of the basic principles of vibrations theory to analyze for themselves many of the vibrations problems that they will encounter in practice, while recognizing the need for a vibrations specialist to solve some more complicated problems. The student will learn to develop mathematical models, and to use these models for analyses which lead to rapid solutions to the problems at hand. Many aspects of these analyses will be supported by Matlab & Simulink. Most of the situations dealt with in this course will be of the lumped-parameter variety, although there will be an introduction to continuous systems , for which the lumped-parameter models become inadequate.

A section of the course is devoted to the vibration of rotating machinery, one of the most common sources of vibrations problems. Some hands-on experience with vibrations-measuring equipment, such as accelerometers and frequency-spectrum analyzers, is provided in the laboratory experiments.

Finally, the effects of whole-body vibration and airborne noise on humans in the workplace will be discussed.

In summary, then, this course aims to achieve considerable competence in modeling, analysis and practical resolution of many or most lumped-parameter vibrations problems, with special reference to issues commonly encountered in design and in the engineering / production workplace. The course also aims to develop sufficient expertise to enable useful discussion with vibrations experts, on occasions when more complex vibrations problems present themselves.

Course Outline

[Note that the following Outline may change a bit as we move along.]

Week	Topic	Reference
1.	Introduction – SDOF Free Vibration, Modeling, Experimental Meas't	Chapter 1, 1.1 – 1.6
2.	Introduction – Design, Stability, Numerical Simulation Sinusoidally-Forced Vibration – Harmonic Excitation	Chapter 1 Chapter 2, ~ 2.1 – 2.3
3.	Sinusoidally-Forced Vibration – Base Excitation, Rotating Unbalance, Measurement Devices, Numerical Simulation, Nonlinear Responses	Chapter 2, remainder
4.	General Forced Response -- quick Multiple-DOF Systems -- Modeling, and Normal-Mode $?_n$'s and Shapes	Chapter 3 Chapter 4, 4.1 – 4.2
5.	Multiple-DOF Systems – Modal Analysis, Mode Summation	Chapter 4, 4.3 – 4.4
6.	Multiple-DOF Systems – Damping, Forced Response, Lagrange Multiple-DOF Systems -- Forced Response & Bode Plots	Chapter 4, 4.5 – 4.8 Handouts
7.	Multiple DOF Systems – Eigenvalue Problems, Numerical Simulation Design for Vibration Suppression	Chapter 4, 4.9 – 4.10 Handouts Chapter 5, 5.1, 5.2, 5.9
	Study Break	
8.	**Review** **Mid-Term Test** Design for Vibration Suppression, continued	 Chapter 5, remainder
9.	Vibration of Rotating Machinery	Handouts
10.	Vibration of Rotating Machinery, continued	Handouts
11.	Vibration Testing and Experimental Modal Analysis Geared and Branched Systems	Chapter 7, sel. topics Handouts
12.	The Effect of Vibration on Humans Vibration of Distributed-Parameter Systems Finite-Element Method	Handouts Chapter 6 Chapter 8
13.	**Review**	

Laboratory Experiments

There are three laboratory experiments in the class :

(1) The first experiment deals with finding experimentally the center of mass and moment of inertia of an irregular shape using two different types of pendulums. **~ Week 3**

(2) The second experiment requires the design and installation of a dynamic vibration absorber as a vibration-control device for a small structure. **~ Week 7**

(3) The third experiment involves the determination of the natural frequencies of a rotating machine using three different techniques, and fault diagnosis based upon the frequency spectrum of accelerometer measurements taken from the machine's bearing housings. **~ Week 10**

The second and third experiments make use of LabVIEW, a graphical programming language for the acquisition and processing of the experimental data.

Grades

Grades will be determined as follows:

Assignments	10 %
Lab Reports	10 %
Midterm Examination	30 %
Final Examination	50 %

100 %

The Examinations will be open-text + formula sheet. You will be able to bring with you only a basic, non-programming calculator.

To obtain credit for the 'Assignment' portions of the grade, a passing grade must be earned in the Exam components. If a total of less than 40/80 is earned in those Exam components, they alone will determine the final result.

A 'Makeup Test' will not be available, except in the case of the Final Exam. If the Midterm Test is missed, for normally-excused reasons, presentation of appropriate documentation will earn the right to write the Final Exam for enough extra credit to replace the missed Test.

Numerical results will be translated into letter grades (A+, A, A-, …) using the standard scheme which appears at www.dal.ca/~engiwww/grades.html .

Please note that there will be **no** Supplemental Examination in this class.