**THE UNIVERSITY OF WESTERN ONTARIO - FACULTY OF ENGINEERING SCIENCE**

**DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING**

# CEE490 - DYNAMICS OF STRUCTURES COURSE OUTLINE - 2003-2004

Students are introduced to concepts of structural dynamics and the response of civil engineering structures to time-varying loads, including those due to wind and earthquakes. This requires the extension of structural theory to include the effects of the mass and damping and to evaluate the action of various deterministic and random dynamic loads. The importance of dynamic loads in the design of dynamically sensitive civil engineering structures, such as tall buildings, towers and chimneys and long span bridges is examined and their treatment in the National Building Code of Canada is reviewed. Topics includes:

- Equation of motion of single-degree-of-freedom systems;
- Free and forced vibrations;
- Response spectra;
- Numerical evaluation of dynamic response;
- Generalised single-degree-of-freedom systems;
- Rayleigh's method;
- Multi-degree-of-freedom systems and forced vibrations;
- Response to random loads;
- Response to Gusting wind;
- Behaviour of structures under seismic loads
- Fatigue

## Prerequisites:

CEE340a, CEE341b, CEE342a

Note: It is the **student's responsibility** to ensure that all Prerequisite and/or Corequisite conditions are met or that special permission to waive these requirements has been granted by the Faculty. It is also **student's responsibility** to ensure that they have not taken any course listed as an Antirequisite. The student may be dropped from the course or not given credit for the course towards their degree if they violate the Prerequisite, Corequisite or Antirequisite conditions.

## Corequisites:

None

## Antirequisites:

ES226a, ES427a/b, ES490

**Contact Hours:**

2 lecture hours per week; 2 tutorial hours per week; (recommended additional personal study 3 hours). Attendance at the tutorial session is **mandatory**.

**Instructor:**

For Term a: Dr. H. P. Hong, P. Eng. ESB3028; e-mail: hongh@fes.engga.uwo.ca; *Secretary*: Room 3005

For Term b: John Kilpatrick, P.Eng., WT150, Ext. 88144; *Secretary*: WT Room 103

**Textbook:**

M. Novak, (expanded by N. Isyumov) "Dynamics of Structures", Lecture Notes - CEE490.

Chopra, A.K., Dynamics of Structures, Theory and Applications to Earthquake Engineering, Prentice Hall, 2000.

Prepared class notes by H. P. Hong will also be available in library.

**Other References:**

Clough, Penzien, *"Dynamics of Structures"*, McGraw-Hill, 1993

M. Paz, *"Structural Dynamics"*, Van Nostrand Reinhold Co., 1985.

Hurty, Rubinstein, *"Dynamics of Structures"*, Prentice-Hall, 1964

Biggs, *"Introduction to Structural Dynamics"*, McGraw-Hill, 1964

**Units:**

SI units will be used in lectures and examinations

**Specific Learning Objectives:**

1. Equation of motion of single-degree-of-freedom systems. At the end of this section, the student should able to:
   a) Understand the concept of damping, mass stiffness and motion, and their relation
   b) Idealise the motion and derive mathematical description of motion

2. Free and forced vibrations of single-degree-of-freedom. At the end of this section, the student should able to apply knowledge of mathematics, science and engineering to:
   a) Solve the differential equation of motion, and describe free vibration
   b) Find natural frequency, and resonant response
   c) Differentiate between the responses of undamped and damped vibration
   d) Calculate response to harmonic and periodic excitation, transmissibility
   e) Understand human response to vibrations
   f) Calculate response to arbitrary, step and pulse excitations using Duhamel's integral

3. Numerical evaluation of dynamic response. At the end of this section, the student should recognise the need of using numerical methods in dynamics of structures. The student should able to compute the dynamic response by implementing the following in spreadsheet

   a) Method based on interpolation of excitation

   b) Central difference method

   c) Newmark's method, Wilson's method

4. Response spectra.

   a) Understand the response spectrum concept

   b) Identify the relations between deformation, pseudo-velocity and pseudo-acceleration spectra

   c) Recognise the difference between design and response spectra

   d) Design simple structures using response spectra

5. Generalised single-degree-of-freedom systems and Rayleigh's method

   a) Understand the representation of motion in generalised coordinate

   b) Idealise and draw the shape function

   c) Derive and solve equation of motion for continuous beam subject to lateral force, and support motion

   d) Derive and solve equation of motion lumped mass system

   e) Calculate frequencies using Rayleigh's method

6. Multi-degree-of-freedom systems and forced vibrations.

   a) Derive equation of motion for multi-degree-of-freedom systems (MDOF)

   c) Calculate eigenvalues and eigen vectors

   d) Solve MDOF systems using modal analysis and superposition

   e) Determine response to ground motion based on spectral approach

7. Response to random loads.

   a) Understand basic concepts of stochastic process, correlation and autocorrelation functions

   b) Apply concept of power spectral density function for wind and earthquake engineering

   d) Draw conclusion from peak factor

8. Response to gusting wind.

   a) Design structures according to National Building Code of Canada for wind load

9. Fatigue
    a) Recognise the fatigue problem due to repeated loading
    b) Design structures coping with fatigue

Instructors may expand on material presented in the course as appropriate

**Evaluation:**

The final course mark will be determined as follows:

| | |
|---|---|
| Performance with quizzes, weekly problems, assignments, and presentations | 40% |
| Two Final Examinations (term a & term b), 3 hours | 60% |
| | 100% |

**Note:**

Students must pass the final examination to pass this course. Students who fail the final examination will be assigned the aggregated mark as determined above, or 48%, whichever is less.

**Quiz and Examination:**

Three 1-hour quizzes (closed book) will be held during the year in the tutorial period. A three-hour final examination will be held during the examination period on all work covered during the course. The schedules of quizzes are to be determined. Only non-programmable calculators are allowed.

The quizzes and the final examination will be closed book: non-programmable calculators are allowed and, **NO** other external sources of information, including books, notes or crib sheets, are permitted.

**Assignments:**

Weekly problems are assigned during tutorial session and the solutions are discussed and reviewed in detail during the tutorial session. (For term a, one solution to Part A of each weekly assignment must be turned in by each student at the end of tutorial period. Each student must turn in one solution to Part B of each weekly assignment at 9:00 AM Monday morning in locker 60, second floor, Engineering Science Building.) Also, there are four assignments besides the weekly problems for the full year. They will be marked and returned. Late assignment will receive a grade of zero. Extensions are to be negotiated with the course instructors, not the teaching assistants.

**Use of English:**

In accordance with Senate and Faculty Policy, students may be penalised up to 10% of the marks on all assignments, tests, and examinations for the improper use of English. Additionally, poorly written work with the exception of the final examination may be returned without grading. If resubmission of the work is permitted, it may be graded with marks deducted for poor English and/or late submission.

**Cheating:**

University policy states that cheating is a scholastic offence. The commission of a scholastic offence is attended by academic penalties that might include expulsion from the program. If you are caught cheating, there will be no second warning.

**Attendance:**

Any student who, in the opinion of the instructor, is absent too frequently from class, laboratory, or tutorial periods will be reported to the Dean (after due warning has been given). On the recommendation of the Department concerned, and with the permission of the Dean, the student will be debarred from taking the regular final examination in the course.

**Conduct:**

Students are expected to arrive at lecture on time, and to conduct themselves during class in a professional and respectful manner that is not disruptive to others.

**Sickness and Other Problems:**

Students should immediately consult with the instructor of Department have any problem that could affect their performance in the course. Where appropriate, the problems should be documented (see attached). The student should seek advice from the Instructor or Department Chair regarding how best to deal with the problem. Failure to notify the Instructor or Department Chair immediately (or as soon as possible thereafter) will have a negative effect on any appeal.

**Notice:**

Students are responsible for regularly checking their e-mail and notices posted outside the Civil and Environmental Engineering Department Office.

**Consultation:**

Student are encouraged to discuss problems with their teaching assistant and/or instructor in tutorial sessions. Office hours will be arranged for the students to see the instructor and teaching assistants. Other individual consultation can be arranged by appointment with the appropriate instructor.

**Course Breakdown:** Engineering Science = 39 AU's; Engineering Design = 25.74 AU's; Science = 13.26 AU's.

The attached document "INSTRUCTIONS FOR STUDENTS UNABLE TO WRITE TESTS OR EXAMINATIONS OR SUBMIT ASSIGNMENTS AS SCHEDULED" is part of this course outline.