Graduate Council Doc. No.10-16c

Mechanical Engineering

Spring 2012

INSTRUCTIONS: Please check the items below which describe the purpose of this request.

1. New course with supporting documents (complete proposal form)
2. Add existing course offered at another campus
3. Expiration of a course
4. Change in course number
5. Change in course title
6. Change in course credit type
7. Change in course attributes
8. Change in instructional hours
9. Change in course description
10. Change in course requisites
11. Change in semesters offered
12. Transfer from one department to another

PROPOSED:

Subject Abbreviation: ME
Course Number: 54900
Long Title: Practical Experiences in Vibrations

EXISTING:

Subject Abbreviation
Course Number

TERMS OFFERED:

Check All That Apply:
- Fall
- Spring
- Summer

CAMPUS(ES) INVOLVED:
- Calumet
- Cont Ed
- Ft. Wayne
- Indianapolis
- N. Central
- Tech Statewide
- W. Lafayette

CREDIT TYPE

1. Fixed Credit: Cr. Hrs: 3
2. Variable Credit Range: Minimum Cr. Hrs (Check One)
   - To
   - Or
   - No
3. Equivalent Credit: Yes
4. Thesis Credit: Yes

COURSE ATTRIBUTES: Check All That Apply

1. Pass/No Pass Only
2. Satisfactory/Unsatisfactory Only
3. Repeatable
4. Credit by Examination
5. Special Fees
6. Registration Approval Type
   - Department
   - Instructor
7. Variable Title
8. Honors
9. Full Time Privilege
10. Off Campus Experience

COURSE DESCRIPTION (INCLUDE REQUISITES/RESTRICTIONS):

ME 54900 Experimental Vibrations, Sem. 2, Class 2, Lab 3, cr. 3. Prerequisite: ME 37500
Theory and application of experimental structural dynamics. Experimental techniques in model analysis, impedance modeling, and basic nonlinear vibrations. Time, frequency, and spatial characteristics of vibrating systems. Virtual and real-time demonstrations and experiments. Vehicular vibration in ride, machinery diagnostics, and health monitoring of structural materials and components. Professor Adams.

OFFICE OF THE REGISTRAR

SEE ATTACHED COPY FOR SIGNATURES
ME 552 Experimental Vibrations, Sem. 2, Class 2, lab 3, cr. 3. Prerequisite: ME 375.

Theory and application of experimental structural dynamics. Experimental techniques in model analysis, impedance modeling, and basic nonlinear vibrations. Time, frequency, and spatial characteristics of vibrating systems. Virtual and real-time demonstrations and experiments. Vehicle vibrations in ride, machinery diagnostics, and health monitoring of structural materials and components.
TO: The Engineering Faculty

FROM: The Faculty of the School of Mechanical Engineering

RE: New Course – ME 552 Experimental Vibrations

The Faculty of the School of Mechanical Engineering has approved the following new course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

ME 552 Experimental Vibrations
Sem. 2, Class 2, lab 3, cr. 3
Prerequisite: ME 375

Theory and application of experimental structural dynamics. Experimental techniques in model analysis, impedance modeling, and basic nonlinear vibrations. Time, frequency, and spatial characteristics of vibrating systems. Virtual and real-time demonstrations and experiments. Vehicle vibrations in ride, machinery diagnostics, and health monitoring of structural materials and components.

Reason: This course has been taught six times on an experimental basis with the following enrollments: spring 02 - 14 students, spring 03 - 13 students, spring 2004 - 14 students, spring 2005 - 16 students, spring 2007 - 18 students, and spring 2008 - 17 students. This course provides students with practical hands-on experiences in vibration measurement, transducers and other issues related to experimental vibration techniques. As such, this course is a valuable complement to other analytical vibration courses.

James D. Jones, Associate Head/Professor
School of Mechanical Engineering

APPROVED FOR THE FACULTY
OF THE SCHOOLS OF ENGINEERING
BY THE ENGINEERING
CURRICULUM COMMITTEE

ECC Minutes #11

Date 12/14/09

Chairman ECC R. Cipra
# Experimental Vibrations

## Course Outcomes

1. Introduce/review the theory of *linear mechanical vibrations*.
2. Learn how to model and analyze single/multi-degree-of-freedom (SDOF/MDOF) systems in free and forced vibration.
3. Learn how to *plan experiments/tests* and interpret dynamic response data using modern technology.
4. Introduce basic *experimental methods*, *vibration hardware* and *advanced analysis techniques* like modal analysis, impedance modeling, and experimental nonlinear vibration.

<table>
<thead>
<tr>
<th>Fundamentals SDOF (review) – 2 wks</th>
<th>Fundamental MDOF (review) – 3 wks</th>
<th>Modal Analysis – 4 wks</th>
<th>Impedance Models – 3 wks</th>
<th>Intro. to Nonlinear Vibration – 3 wks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Assumptions and nomenclature</td>
<td>1. Free vibration</td>
<td>1. Modal superposition</td>
<td>1. Impedance models</td>
<td>1. Qualitative methods</td>
</tr>
<tr>
<td>2. Degrees-of-freedom</td>
<td>- Poles/eigenvalues</td>
<td>- Single to multiple DOFs</td>
<td>- Input-output models</td>
<td>- State space/geometric</td>
</tr>
<tr>
<td>3. Inertia, damping, stiffness</td>
<td>- Eigen-/modal vectors</td>
<td>- Experimental methods</td>
<td>- Dynamic stiffness</td>
<td>- Phase plane projection</td>
</tr>
<tr>
<td>4. Laplace transforms</td>
<td>- Coord. transformation</td>
<td>- Sinusoidal I-O</td>
<td>- Dynamic compliance</td>
<td>- Poincare maps</td>
</tr>
<tr>
<td>5. Transfer functions, frequency response, impulse response</td>
<td>- Coupling (static/dyn.)</td>
<td>- Frequency response</td>
<td>- Compatibility and continuity constraints</td>
<td>2. Basic phenomena</td>
</tr>
<tr>
<td>6. Free/forced vibration</td>
<td>- Modal superposition</td>
<td>- Damped Complex Expn.</td>
<td>- Components and assembly</td>
<td>- Fixed points/orbits</td>
</tr>
<tr>
<td>7. Time/freq./spatial concepts</td>
<td>2. Forced vibration</td>
<td>- Mathematical I-O</td>
<td>2. Perturbed boundary conditions</td>
<td>- Nonlinear resonance</td>
</tr>
<tr>
<td>3. General damping</td>
<td>- Fourier series and superposition</td>
<td>- Model order</td>
<td>- Mass, damping, stiffness</td>
<td>- Bifurcation, etc.</td>
</tr>
<tr>
<td>- Proportional</td>
<td>- Relationship to modal parameters</td>
<td>- SDOF techniques</td>
<td>- Nonlinear connections</td>
<td></td>
</tr>
<tr>
<td>- Non-proportional</td>
<td></td>
<td>- Low order techniques</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Effects on FRF and impulse response</td>
<td></td>
<td>- High order techniques</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>- Residue estimation</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>- Modal data validation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Laboratory Experiments - Weekly

1. Structural dynamic impedance analysis and modeling
   - FRF estimation, MIMO testing, sub-structuring
2. Structural dynamic modal analysis and modeling
   - Model order, modal parameter estimation, impact testing
3. Introduction to experimental nonlinear dynamics and vibrations
   - Periodic response, Poincare maps, harmonic distortion

## Experimental Considerations

1. Hardware
   - Transducers
   - Signal conditioners
   - Front-end
2. Signal processing
   - Time domain
   - Frequency domain
   - Fourier analysis
   - Excitation methods
**COURSE NUMBER:** ME 552

**REQUIRED COURSE OR ELECTIVE COURSE:** Elective

**TEXTBOOK/REQUIRED MATERIAL:** Class Notes

**COORDINATING FACULTY:** D. Adams

**COURSE DESCRIPTION:** Theory and application of experimental structural dynamics. Experimental techniques in modal analysis, impedance modeling, and basic nonlinear vibrations. Time, frequency, and spatial characteristics of vibrating systems. Virtual and real-time demonstrations and experiments. Vehicle vibrations in ride, machinery diagnostics, and health monitoring of structural materials and components.

**ASSESSMENTS TOOLS:**
1. Weekly homework assignments.
2. One 1-hour exam.
3. Four laboratory reports.
4. One comprehensive final exam.

**PROFESSIONAL COMPONENT:**
1. Engineering Topics: Engineering Science – 2.5 credits (83%)
   Engineering Design – 0.5 credits (17%)

**NATURE OF DESIGN CONTENT:** Contained in the lecture material and several homework assignments are problems which relate to the design of algorithms (software) to perform specific tasks involving data characterization and parameter estimation. Also in lecture and homework are problems relating to the design of measurement systems for vibration experiments to meet specified needs for accuracy and certain kinds of input/output data.

**COMPUTER USAGE:** Students will need to use MATLAB to develop and write subroutines and make extensive use of graphics terminals and MATLAB graphics subroutines.

**COURSE STRUCTURE/SCHEDULE:**
1. Lecture – 2 days per week at 50 minutes.
2. Laboratory – 1 day per week at 150 minutes.

**COURSE TITLE:** Experimental Vibrations

**TERMS OFFERED:** Spring

**PRE-REQUISITES:** ME 375 System Modeling and Analysis

**COURSE OUTCOMES:**
1. Introduce/revise the theory of linear mechanical vibrations.
2. Learn how to model and analyze single/multi-degree-of-freedom (SDOF/MDOF) systems in free and forced vibration.
3. Learn how to plan experiments/tests and interpret dynamic response data using modern technology.
4. Introduce basic experimental methods, vibration hardware and advanced analysis techniques like modal analysis, impedance modeling and experimental nonlinear dynamics.

**RELATED ME PROGRAM OUTCOMES:** N/A

**PREPARED BY:** D. Adams

**REVISION DATE:** April 26, 2007
A. Justification for the Course:

- This course has been taught six times on a experimental basis with the following enrollments: spring 2002 – 14 students, spring 2003 – 13 students, spring 2004 – 14 students, spring 2005 – 16 students, spring 2007 – 18 students, and spring 2008 – 17 students. This course provides students with practical hands-on experiences in vibration measurement, transducers and other issues related to experimental vibration techniques. As such, this course is a valuable complement to other analytical vibration courses.
- The purpose of ME 552 course is an advanced vibrations course that focuses both on analytical analysis methods, but also advanced experimental methods (e.g. model analysis, impedance modeling, and experimental nonlinear dynamics). As such it is designed as an entry-level graduate course. Enrollment is anticipated to run 15-20 students annually, with perhaps a few undergraduate students participating.

B. Learning Outcomes and Methods of Evaluation or Assessment:

- 1) Introduce/review the theory of linear mechanical vibrations, 2) Learn how to model and analyze single/multi-degree-of-freedom (SDOF/MDOF) systems in free and forced vibration, 3) Learn how to plan experiments/tests and interpret dynamic response data using modern technology, 4) Introduce...
basic experimental methods, vibration hardware and advanced analysis techniques like modal analysis, impedance modeling and experimental nonlinear dynamics.

- Weekly homework assignments, one 1-hour exam, four laboratory reports, and one comprehensive final exam

- Engineering Topics: Engineering Science – 2.5 credits (83%) & Engineering Design – 0.5 credits (17%)
  
  **Criteria:**
  
  | ☑️ Exams and Quizzes | ☑️ Papers and Projects |
  | ☐️ Homework           | ☐️ Laboratory Exercises |
  | ☐️ Attendance and Class Participation | ☐️ Extra Credit Policies |

- This course is taught by lecture and lab and the program outcomes are described in the program map.

  **Method of Instruction:**
  
  | ☑️ Lecture | ☐️ Recitation |
  | ☐️ Presentation | ☑️ Laboratory |
  | ☐️ Lab Prep | ☐️ Studio |
  | ☐️ Distance | ☐️ Clinic |
  | ☐️ Experimental | ☐️ Research |
  | ☐️ Ind. Study | ☐️ Pract/Observe |
  | ☐️ Seminar |

C. **Prerequisite(s):**

- ME 37500 – System Modeling and Analysis
- Students will need to use MatLab to develop and write subroutines and make extensive use of graphics terminals and MatLab graphics subroutines.

D. **Course Instructor(s):**

- Douglas E. Adams, Professor of Mechanical Engineering
- Is the instructor currently a member of the Graduate Faculty?  ☑️ Yes  ☐️ No

(If the answer is no, indicate when it is expected that a request will be submitted.)

E. **Course Outline:**

F. **Reading List (include course text):**

- Class Notes
- No textbook required.

G. **Library Resources:**

- No resources needed.

H. **Example of a Course Syllabus:**

**ME 597A COURSE SYLLABUS**

<table>
<thead>
<tr>
<th>Period</th>
<th>Topic</th>
<th>Reading Assignment</th>
<th>Laboratory</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction to course and practical applications</td>
<td>Chap. 1</td>
<td>NO LAB</td>
</tr>
<tr>
<td>2</td>
<td>Applications (continued)</td>
<td>Chap. 1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Modeling</td>
<td>Chap. 1</td>
<td>Orientation</td>
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<tr>
<td>4</td>
<td>Modeling</td>
<td>Chap. 2</td>
<td>~All</td>
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<tr>
<td>5</td>
<td>Modeling</td>
<td>Chap. 2</td>
<td>LAB #1</td>
</tr>
<tr>
<td>6</td>
<td>Modeling</td>
<td>Chap. 2</td>
<td>~Individual</td>
</tr>
<tr>
<td>7</td>
<td>Modeling</td>
<td>Chap. 2</td>
<td>PROJECT</td>
</tr>
<tr>
<td>8</td>
<td>Analysis</td>
<td>Chap. 3</td>
<td>~Group</td>
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<tr>
<td>9</td>
<td>Analysis</td>
<td>Chap. 3-4</td>
<td>LAB #2</td>
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<tr>
<td>10</td>
<td>Analysis</td>
<td>Chap. 4</td>
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<tr>
<td>11</td>
<td>Measurement</td>
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<td>PROJECT</td>
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<tr>
<td>12</td>
<td>Measurement</td>
<td>Notes/lab</td>
<td>~Group</td>
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<tr>
<td>13</td>
<td>Measurement</td>
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<td>EXAM I, In-class exam (February 24, 2010)</td>
<td>Periods 1-10</td>
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<td>------------------------------------------</td>
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<tr>
<td>14 Signal processing</td>
<td>Notes/lab</td>
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<tr>
<td>15 Signal processing</td>
<td>NOTES/lab</td>
<td>PROJECT</td>
<td></td>
</tr>
<tr>
<td>16 Signal processing</td>
<td>Notes/lab</td>
<td>~Group</td>
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<tr>
<td>17 Data analysis</td>
<td>Notes/lab</td>
<td>PROJECT</td>
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<tr>
<td></td>
<td>~Group</td>
<td></td>
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<tr>
<td>No class -- Spring vacation</td>
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<tr>
<td>18 Experimental modal analysis</td>
<td>Notes/lab</td>
<td>PROJECT</td>
<td></td>
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<tr>
<td>19 Experimental modal analysis</td>
<td>Notes/lab</td>
<td>~Group</td>
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<tr>
<td>20 Experimental modal analysis</td>
<td>Notes/lab</td>
<td>PROJECT</td>
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</tr>
<tr>
<td>21 Experimental modal analysis</td>
<td>Notes/lab</td>
<td>~Group</td>
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</tr>
<tr>
<td>22 Experimental modal analysis</td>
<td>Notes/lab</td>
<td>PROJECT</td>
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<tr>
<td>23 Experimental modal analysis</td>
<td>Notes/lab</td>
<td>~Group</td>
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<tr>
<td>24 Impedance modeling</td>
<td>Notes/lab</td>
<td>PROJECT</td>
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</tr>
<tr>
<td>25 Impedance modeling</td>
<td>Notes/lab</td>
<td>~Group</td>
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<tr>
<td>26 Impedance modeling</td>
<td>Notes/lab</td>
<td>PROJECT</td>
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<tr>
<td>27 Impedance modeling</td>
<td>Notes/lab</td>
<td>~Group</td>
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<tr>
<td>Final Presentations (During lab period, April 19-23)</td>
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<tr>
<td>Final Presentations (During lab period, April 19-23)</td>
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