**Basic Structural Dynamics and Vibration Techniques**
**Dr. Peter Avitabile, PE**

**Description**:

This course is derived from a series of undergraduate and graduate level courses taught at the University of Massachusetts Lowell (Dynamic Systems, Vibrations, Spectral Analysis, Structural Dynamic Modeling Techniques, Experimental Modal Analysis, Structural Dynamics) by Dr. Peter Avitabile over the past 2 decades. The topics from these courses are extracted and presented into an industry style format to allow for maximum, relevant, pertinent material to be shown in an application style. Graduate level course homework and projects typically given are replaced with tutorial and explanatory presentations that encompass the main learning experiences typically achieved in a university course.

The material in this blended industry style course addresses the fundamentals of structural dynamics and vibration analysis of 1, 2 and multi DOF mechanical systems including the effects of damping, free response, forced response to transient and steady state harmonic and periodic excitations. The significance of natural modes, resonance frequency, mode shape, and orthogonality are addressed. Topics of vibration absorbers, time and frequency analysis, Fourier Transforms, and spectral processing basics are covered. Some finite element modeling for dynamic analysis is also included. A very brief overview of experimental modal analysis and vibrations testing is also included. Specialty topics covering basics of random vibrations, shock analysis and seismic analysis are all explained in terms of the basic tools covered in this course.

Examples are provided throughout the course using MATLAB to illustrate points covered; the student will have access to existing scripts that can be modified and altered for additional self-learning and exploration for topics covered.

All course notes are voice annotated and examples are also presented in this format. This allows students to revisit material as they progress through all the topics that are addressed. The goal of the course is to provide the critical understanding of material related to structural dynamics and vibration problems

**Who should take this course**:

This course is intended to give a very complete, solid background for the engineer working in a company where structural dynamic modeling issues are important. The material is intended to allow the recent undergraduate to ramp up quickly to become productive in a short period of time and understand some of the basic relevant topics related to structural dynamics applications typically encountered. This course is also useful for those who have not been involved in this area and have a need to become more familiar with the techniques and approaches used for structural dynamic applications.

**Topics to be Addressed:**

- **Review of Structural Dynamic Modeling Techniques**
  (a broad discussion of the scope to be covered)
- **Basic Single Degree of Freedom Systems**
  Definitions, Free Vibrations, Forced Vibrations, Transient Vibrations
- **Multiple Degree of Freedom Systems**
  Static and Dynamic Coupling, Modal Uncoupling, Proportional and Complex Damping,
  Modal Space, Orthogonality, Independence, Mode Superposition,
  Laplace Domain, System Transfer Function, Frequency Response Function
  Time vs Frequency Approaches for Response Prediction
- **Finite Element Modeling Overview**
  Nodes, Elements, System Assembly, Boundary Conditions
- **Structural Dynamic Modification**
  Brief overview, modal and response based modification
- **System Modeling Overview**
  Component Mode Synthesis, Reduced Order Models, Expansion Methods, Impedance Models
- **Computational Methods**
  Static Decomposition, Eigensolutions, Propagation Methods
  Time Domain Methods, Frequency Domain Methods, Mode Superposition
- **Experimental Modal Analysis**
  Basic Measurement Topics including Signal Processing for Development of FRF Measurements,
  Impact and Shaker Excitation Techniques, Modal Parameter Estimation and Model Validation
- **Analytical and Experimental Model Correlation Basics**
  FEA and Test correlation; MAC, CoMAC, Orthogonality
- **Advanced Topics**
  Random Vibrations, Shock Analysis/Testing Considerations, Seismic Applications
- **Linear Algebra Topics**
  Identification of critical linear algebra predominantly used in structural dynamic modeling

- **Examples**
  Three DOF model – application for boundary condition identification, seismic anchor design, etc
  Two DOF model system response – mode superposition
  (full description of the development of a modal model in modal space)
  Multi-DOF wind turbine blade model – forced response and mode superposition
  Cantilever Beam Model – different approaches for boundary condition identification
  Reduced order model – comparison of different techniques
  SDM and System Model development – simple support and system model development
  Correlation – BU model and test correlation

## **Basic Structural Dynamics and Vibration Techniques** (PPT and MP4 files by topic)

| Chapter | Topic | Time (min) | Revision |
|---|---|---|---|
| 00 | Intent | 06.54 | 062718 |
| 01 | Overview | 37.50 | 062718 |
| | | | |
| 02a | General Math Review | 23.17 | 062718 |
| 02b | Time Response | 20.37 | 062718 |
| 02c | Fourier Series | 12.08 | 062718 |
| 02d | Laplace Transforms | 09.47 | 062718 |
| 02e | Block Diagrams | 08.05 | 062718 |
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| 03a | Mechanical Systems | 11.02 | 062718 |
| 03b | Basic Elements | 07.31 | 062718 |
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| 04a | SDOF Definitions | 24.16 | 062718 |
| 04b | SDOF Initial Conditions | 12.23 | 062718 |
| 04c | SDOF Forced Response | 24.49 | 062718 |
| 04d | SDOF Arbitrary Response | 15.57 | 062718 |
| 04e | SDOF Transfer Function and FRF | 11.09 | 062718 |
| 04f | SDOF State Space | 08.16 | 062718 |
| 04g | SDOF Polynomial IO Equations | 06.03 | 062718 |
| 04h | SDOF Linearization | 01.46 | 062718 |
| 04i | SDOF Important Features | 13.28 | 062718 |
| | | | |
| 05a | MDOF Free Body Diagram | 09.00 | 062718 |
| 05b | MDOF Eigensolution | 06.42 | 062718 |
| 05c | MDOF Orthogonality | 03.13 | 062718 |
| 05d | MDOF Modal Space | 18.39 | 062718 |
| 05e | MDOF Laplace Domain | 12.08 | 062718 |
| 05f | MDOF Tuned Absorber | 11.40 | 062718 |
| 05g | MDOF Two DOF FRF | 04.26 | 062718 |
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| 06a | Solid Mechanics Review | | |
| 06b | FEM Review | 26.17 | 062718 |
| 06c | FEM Modeling Examples | 06.25 | 062718 |
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| 07 | Model Reduction Expansion | 12.07 | 062718 |
| 08 | Structural Dynamic Modification | 16.50 | 062718 |
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| 09a | System Modeling Concepts Modal | 13.07 | 062718 |
| 09b | System Modeling Concepts Impedance | 12.08 | 062718 |
| 09c | System Modeling Concepts CMS | 09.54 | 062718 |
| 09d | System Modeling Comparison | 19.45 | 062718 |
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| 10a | Static Decomposition | 06.39 | 062718 |
| 10b | Eigensolutions | 10.20 | 062718 |
| 10c | Propagation Methods | 21.32 | 062718 |
| 10d | Mode Superposition | 07.58 | 062718 |
| 10e | Frequency Domain Methods | 02.38 | 062718 |
| 10f | Shock Response Spectrum | 12.36 | 062718 |
| 10g | Random Analysis | 10.08 | 062718 |
| 10h | Time Frequency Response Explanation | 06.28 | 062718 |
| | | | |
| 11 | Modal Primer | 38.28 | 062718 |
| 12a | Correlation Topics | 14.10 | 062718 |
| 12b | Correlation Issues | 17.22 | 062718 |
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| AA | Linear Algebra Review | 17.34 | 062718 |

======= Tutorial Materials

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|---|---|---|
| T-A | General Matlab Simulink information | |
| T-B | First Order System Tutorials | |
| T-C | Second Order System Tutorials | |
| T-D | Two DOF Motor Tutorial | |