EM731 “Aeroelasticity”

Spring 2012
Tuesdays and Thursdays, 7:00 to 8:15 PM
Engineering Bldg, Room E 423B
San Diego State University

Instructor

Dr. Luciano Demasi
Assistant Professor

Department of Aerospace Engineering and Engineering Mechanics
Room E.307, Engineering Building

Tel. 619 594 3752

email ldemasi@mail.sdsu.edu
personal webpage www.lucianodemasi.com

Please make sure to include the course name, EM731, in any email correspondence.

Office Hours

Tuesday and Thursday 9:30am-10:30pm
Friday 2pm-4pm (only by appointment)

Textbook

Dewey H. Hodges and G. Alvin Pierce, *Introduction to Structural Dynamics and Aeroelasticity*, Cambridge University Press, ISBN 0-521-80698-4

Other useful books

The course will occasionally borrow material from other sources. The following is a list of other suggested references.

Finite Element Method

Nam-Ho Kim, Bhavani V. Sankar, *Introduction to Finite Element Analysis and Design*, Wiley, ISBN 978-0-470-12539-7

Dynamic analysis using the Finite Element Method

Bathe K. J, *Finite Element Procedures in Engineering Analysis*, Prentice-Hall civil engineering and engineering mechanics series. Englewood Cliffs, N. J.: Prentice-Hall, 1982

Vibrations and structural dynamics

Ginsberg J. H., *Mechanical and Structural Vibrations: theory and applications*, New York: Wiley

Thomson W. T. And Dahleh M. D., *Theory of vibration with applications*, Upper Saddle River, N. J.: Prentice Hall, 1998

Donaldson B. K., *Introduction to Structural Dynamics*, Cambridge aerospace series. Cambridge: Cambridge University Press.

Aeroelasticity

W. P. Rodden, *Theoretical and Computational Aeroelasticity*, published by Crest Publishing, ISBN 978-0692-01241-3

Raymond L. Bisplinghoff, Holt Ashley, Robert L. Halfman, *Aeroelasticity*,
Published by Courier Dover Publications, 1996, ISBN 0486691896, 9780486691893, 860 pages

Earl H. Dowell (editor), Howard C. Curtiss Jr., Robert H. Scanlan, and Fernando Sisto, *A Modern Course in Aeroelasticity*, Kluwer academic Publishers, ISBN 0-7923-0185-4

Prerequisites

Students are expected to have good understanding of vibrations (successful completion of EM611 or equivalent graduate level structural vibrations course), structural dynamics, Finite Element Method and basic knowledge of steady and unsteady aerodynamics (successful completion of AE620 or equivalent course) .
Prior programming skills (MATLAB) are recommended. The students will be asked to use MATLAB when programs need to be written.

Course objectives

The objective of this course is to teach the fundamentals of aeroelasticity. The course provides the necessary background on aerospace structural dynamics and aerodynamics with particular emphasis on the interaction fluid-structure which is typical of aeroelasticity. The course will also introduce the computational tools for the aeroelastic analysis and design of innovative airplane configurations including Joined Wings. The students will gain the theoretical background on the

frequency-domain unsteady aerodynamic panel codes used by the industry (e.g., Doublet Lattice Method) and their coupling with structural commercial Finite Element Method software. Leading commercial software such as **ZAERO** and **NASTRAN** will be discussed. The theory part will be complemented with practical training in using **FEMAP** and **NASTRAN**.

Course Outline

- *Review of structural dynamics concepts*
  - Degrees of Freedom
  - Generalized Coordinates
  - Equations of Motion
  - Mass, Stiffness and Damping matrices
  - Virtual Displacements
  - Virtual Work
  - Generalized Forces
  - Lagrange Equations
  - Natural Modes and Frequencies
  - Reduced Order System of Equations of Motion
  - Continuum Systems
  - Extensional Stiffness, Bending Stiffness, Torsional Stiffness
  - Geometric Conditions
  - Natural Conditions

- *Static aeroelasticity*
  - Divergence
  - Aileron Reversal, Efficiency of the Aileron
  - Uniform Lifting Surface
    - Shear Center
    - Elastic Axis
    - Torsional Divergence
    - Airload Distribution for an Elastic Wing
    - Sweep Effects (Swept-Back and Swept-Forward Wings)
    - Load Distribution for Elastic Swept-Back and Swept-Forward Wings

- *Unsteady Aerodynamics*
  - Substantial Derivative
  - Local Derivative
  - Convective Derivative
  - Compressible Isentropic and Inviscid Flow
  - Continuity Equation
  - Momentum Equation
  - Isentropic Relation
  - Speed of Sound
  - Mach Number
  - Circulation
  - Vorticity
  - Rotational Flow
  - Irrotational Flow

- Velocity Potential
- Bernoulli's Equation
- Lord Kelvin Equation
- Kelvin's Circulation Theorem
- Boundary Conditions
- Linearization of the Equations
- Small Perturbation Velocity Potential
- Pressure Coefficient
- Acceleration Potential
- Two-Dimensional Incompressible Case
- Harmonic Oscillations of an Airfoil
- Mathematical Definition of the Reduced Frequency
- Physical Interpretation of the Reduced Frequency Concept

- *The Doublet Lattice Method*
  - Normalwash
  - Unsteady Aerodynamic Kernel
  - Aerodynamic Mesh
  - Concepts of Load Point and Control Point
  - Concepts of Receiving and Sending Panels
  - Normalwash Factor
  - Generalized Aerodynamic Force Matrix
  - Summary of the Vortex Lattice Method Theory for the Steady Case
  - The Infinite Plate Spline Method
- *Introduction to the Concept of Aeroelastic Flutter*
  - Physical Interpretation of the Classical Flutter
  - Modal Damping and Modal Frequency
  - Concepts of Stability, Stability Boundary and Instability
  - Calculation of the Flutter Speed via P-Method
  - Concept of Coalescence of Modal Frequencies
  - Two-Degree-of-Freedom Flutter Model
  - Engineering Solutions for Flutter
    - Review on the Structural Damping and Introduction to the K-Method
    - Concept of Dummy Structural Damping
    - P-K Method
    - Concepts of Violent Flutter, Moderate Flutter and Mild Flutter
    - Prediction of the Divergence Speed with a Flutter Analysis
    - Comparison Between the P Method and K Method
    - G method

- *Derivation of the Aeroelastic Equations in the Time Domain*
- *Derivation of the Aeroelastic Equations in the Frequency Domain*
- *Derivation of the Aeroelastic Equations in the Laplace Domain*
- *Lag Effects*
- *Least Square Method*
- *Rational Form for the Generalized Aerodynamic Force Matrix*
- *Roger Approximation*

- *State Space Representation of the Aeroelastic Equations in the Laplace Domain*
- *Aerodynamic Lag States*
- *Calculation of the Flutter Speed via Root Locus Technique*
- *Nonlinear Aeroelasticity: Consistent Flutter and Divergence Speeds*
- *Linearized Flutter Calculation*
- *Limit Cycle Oscillation*
- *Modally Reduced Order Aerodynamic Model*
- *Aeroelasticity of Joined Wing Configurations: problems and challenges*
- *Calculation of Natural Frequencies and Modes with **FEMAP** and **NASTRAN***
- *Computational Static Aeroelasticity using the software **FEMAP** and **NASTRAN** and Calculation of the Divergence Speed of Different Planar and Non-Planar Wing Configurations*
- *Computational Dynamic Aeroelasticity using the software **FEMAP** and **NASTRAN** and Calculation of the Flutter Speed of Different Planar and Non-Planar Wing Configurations*
- *Calculation of the Divergence Speed via Flutter Analysis with the software **FEMAP** and **NASTRAN***
- *Discussion of other commercial software for aeroelastic analysis such as **ZAERO***

Note: the content of the course may change depending on student's interests and time constraints

Course Competencies

At the close of EM731 you should be able to...

1. Conduct a simplified static aeroelastic analysis.

2. Calculate the flutter speed and frequency of a given wing configuration with different methods.

3. Use the software FEMAP to create FEM models of wing configurations

4. Use the software NASTRAN to calculate the natural modes and frequencies of a given wing system.

5. Use the software NASTRAN to calculate the divergence and flutter speeds of a given wing system.

6. Describe and summarize the main concepts of the subjects covered in the course with the inclusion of examples.

7. Solve problems similar to the ones discussed in the class and/or assigned in the homeworks.

Grading

In order to acknowledge achievements and monitor progress, the Department needs a realistic and meaningful system for grading performance. The University and the professional community expect the Department to maintain standards that reflect its reputation as one of the foremost programs of its type in the country. According to the University's Graduate Bulletin,

A means outstanding achievement; available for only the highest accomplishment;

B means praiseworthy performance; definitely above average;

C means average; awarded for satisfactory performance.

In general, professors in the department award "**A**" grades to acknowledge achievements that go beyond specified course requirements and criteria. By its very nature, this type of performance cannot always be spelled out clearly in advance. "**A**"s are reserved for special efforts that exceed expectations by demonstrating exceptional creativity, boldness, commitment, ingenuity, or elegance.

Grading Factors

Assignment/Activity	% of final grade
Homework. An homework is an assignment that requires several days to be completed. *Collaboration is not allowed*. The homework must be on the desk of the classroom before the lecture starts on the due date. *Late homework will be accepted, with penalty of 20%, on the due date only*. Quality of the presentation of the results (clarity, easy to follow etc.) is crucial. **Projects**. A project is an assignement which requires more time than a regular homework to be completed. *Collaboration is not allowed* unless the project requires a team-work. During the semester invited speakers may give a seminar on a particular subject. In that case the presence of the students will be mandatory and the writing of an essay about the seminar will be required. The essay will be considered as a project.	**40.00**
Exams 1,2 and final exam (or final project). The students will be asked to describe the main concepts of some	**60.00**

subjects covered in the first part of the course and/or to solve some problems similar to the ones analyzed in the class or homeworks before the middle-term exam date. The exams are *closed book and closed notes.* Quality of the presentation of the results (clarity, easy to follow etc.) is crucial.	
TOTAL	**100**

Every assignment or activity will be graded in a scale of 100 points.

Reported Final Grades

A = 90 or higher

B = 80 or higher (but less than 90)

C = 70 or higher (but less than 80)

D = 60 or higher (but less than 70)

The instructor reserves the right to raise or lower the lower limit of each grade range such that division between letter grades occurs at large gaps in the grade spectrum.

Minor adjustments to avoid grades being decided by a fraction of a point may be adopted.

If you feel a mistake was made in grading any material involving (1) points not added or not recorded properly, (2) points taken-off for an answer that is not 100% correct, or (3) for given partial credit, please talk to the instructor either through e-mail or in person during the office hours.

Participation (classes)

Please do not come late to class sessions as it detracts from the learning experience of everyone involved. You should arrange in advance for a partner to take notes and obtain handouts for any class session you cannot attend.
Class participation will be used in deciding borderline grades.

Participation (seminars)

If a seminar is scheduled, all students must be present. Only University approved excuses for absences will be accepted in the case of seminars. Please note that an essay regarding the seminar is required and if you miss the seminar (for University approved excuses) then you can not write the related essay.

Accommodations for Students with Disabilities

Students with disabilities who need support services are encouraged to notify the instructor as soon as possible. This can be done confidentially via email or by phone (see instructor contact information).

Academic honesty

All students admitted to SDSU have signed a statement of academic honesty committing themselves to be honest in all academic work and understanding that failure to comply with this commitment will result in disciplinary action. This statement is a reminder to uphold your obligation as a student at SDSU and to be honest in all work submitted and exams taken in this class and all others

Plagiarism

Plagiarism consists of passing off as yours the work that belongs to someone else. As such, you will be committing plagiarism if you present someone else's work as your own, even with the other person's consent.

Miscellaneous

The use of laptop is allowed in the classrooms for the only purpose of taking notes. *Any other laptop use (e.g. cheking emails or searching the web) must be postponed until the class ends to avoid distractions for the other students*. A violator of this rule will be asked to turn off the computer.

Submitting copy of a homework prepared by somebody else is considered cheating.

Submitting a project which is copied in full or in part from other students' work is considered plagiarism.

Collaboration on a project or homework is not allowed unless specifically allowed by the instructor when the project/homework is assigned.