Fall 2011

CE 131L. Matrix Structural Analysis

Instructor:	Henri Gavin, 162 Hudson Annex, `Henri.Gavin@Duke.edu`
Class Time:	Tu Th 11:40–12:55, Room 207 Hudson
Recitations:	We 4:25–5:40, Room 207 Hudson
T.A.:	Craig Wasilewski, `craig.wasilewski@duke.edu`
Office Hours:	H.P.G.: Th 4pm – 5pm, Rm 162; C.W.: Fr 10am-11am, Rm 053 Hudson; and by appointment
Textbook:	A. Kassimali, *Matrix Analysis of Structures, 2nd ed.,* Brooks/Cole, 2012.
Course Website:	http://www.duke.edu/~hpgavin/ce131/
Prerequisite:	EGR 75L. Solid Mechanics,
Corequisite:	Math 107. Linear Algebra and Diff. Eq'ns
Academic Integrity:	http://www.integrity.duke.edu/ugrad/
Short Term Illness:	http://trinity.duke.edu/academic-requirements
Grading:	Homeworks(11) 30%; Tests(3) 45%; Final(1) 20%; Participation 5%

BULLETIN DESCRIPTION

Development of stiffness matrix methods from first principles. Superposition of loads and elements. Linear analysis by hand and computer of plane and space structures comprising one-dimensional truss and beam elements.

LEARNING OBJECTIVES

The objectives of this course are to teach students how to:

- Distinguish between energy-based flexibility approaches and matrix-based stiffness approaches to structural analysis;
- Determine deflections and forces in statically determinate and indeterminate structures using the matrix stiffness method;
- Understand the physical interpretation of stiffness matrices and use this interpretation to assemble the stiffness matrix analytically;
- Compute deflections and rotations, internal forces and moments, and reactions in trusses, beams and frames; and
- Write and use computer programs which implement the direct stiffness method.

COURSE GOALS

Students who successfully complete this course will demonstrate:

- An ability to apply knowledge of mathematics (linear algebra), science and engineering (material behavior), and computer programming;
- An ability to formulate and solve problems in structural analysis using the matrix stiffness method and to interpret the resulting solutions;
- An understanding of professional and ethical responsibility; and
- A recognition of the need for, and an ability to engage in life-long learning.

MEASURABLE OUTCOMES

This course measures students' progress in meeting the above objectives by requiring them to:

- Calculate the forces within members of trusses, beams, and frames using analytic and computer-based techniques;
- Determine fixed-end reactions using energy-based methods;
- Understand and use the principle of superposition in simplifying the analysis of statically indeterminate structures;
- Apply the stiffness method to determine the behavior of plane trusses, beams, and frames subjected to various loadings;
- Extend the planar analysis to include three-dimensional trusses and frames; and
- Extend the scope of linear static analysis to include stability and dynamic effects.

GENERAL REQUIREMENTS

- **The Duke Community Standard** http://www.integrity.duke.edu/standard.html: Duke University is a community dedicated to scholarship, leadership, and service and to the principles of honesty, fairness, respect, and accountability. Citizens of this community commit to reflect upon and uphold these principles in all academic and non-academic endeavors, and to protect and promote a culture of integrity.

  To uphold the Duke Community Standard:

  - I will not lie, cheat, or steal in my academic endeavors;
  - I will conduct myself honorably in all my endeavors; and
  - I will act if the Standard is compromised.

- **Reading:** Completion of the assigned reading is recommended prior to each lecture. (See the course schedule and reading list on page 4.)

- **Attendance:** Please be on time and please participate during class. Please keep your cell phones and computers off. Please be attentive. (Do I really need to write this?)

- **Communication:** We will use e-mail for out-of-class communication.

- **Extra-curricular and co-curricular activities:** In most cases extra-curricular and co-curricular activities conflicting with course commitments can be resolved easily. Just let me know beforehand.

- **Grading:** The TA will grade your solutions to homework assignments. I will grade the exams. See me (not the TA) about any grading errors.

HOMEWORK REQUIREMENTS

- **Assignments and due dates:** Homework assignments shown on the course schedule and are due at 5:00 pm Fridays. (See page 4.)
- **Collaboration:** You may work with other students and get help from the TAs and the instructor on homework assignments, but do not copy solutions (from any source). Carry out your solutions in a way that makes sense to you.

  The TAs are not allowed to solve homework problems for you. Questions like, "How did you do this problem?" or "What did you get for an answer to Problem 3?" are not appropriate. Don't ask questions like these, and don't answer questions like these. You are not allowed to get help from anyone on the exam. Violations will be handled according to the Duke Community Standard.

  You won't learn anything from copying solutions. It is a violation of the Duke Community Standard. Don't do it.
- **Matlab:** Three homework assignments require MATLAB programming abilities.
- **Short-term illness:** If you miss a due-date because you were sick, follow the university policy for submitting the missed assignment. http://trinity.duke.edu/academic-requirements
- **Extensions:** You are allowed *one homework extension* (from Friday to Monday) during the semester. To obtain an extension, simply send me an e-mail stating your extension request, with Cc to yourself, and with the subject line: `CE131: <your name> extension request` at least 24 hours before the deadline. Attach a print-out of my e-mail reply to the top of your completed assignment.
- **Neatness:** On homework assignments, 15 of the 100 points will be awarded for following these rules:
  - Use a pencil (so you can erase). Mechanical pencils are recommended.
  - Write neatly and clearly. Your TA may lose patience with illegible solution sets.
  - Write your first and last name, the course number, the assignment number and the due-date in the upper right corner of the first page. Write the page number on each page (e.g., 3/6, means page 3 of 6)
  - Write out each problem statement. (i.e., Given=. . . , Find=. . . , Collaborators=. . .)

    For "Collaborators:" list anyone who helped you with the solution. If there are no collaborators just write "none".
  - Use a straight edge (a ruler or a triangle) to draw straight lines.
  - Present solutions to problems in the same order as listed in the assignment, and begin every problem on a new page unless the next solution is so short that it can fit on the same page.
  - Partial credit will be awarded *only* if the solution leading to an incorrect answer describes your thinking in words.
  - Draw a box around your final answer and provide the units associated with your answeri (e.g., mm, kN, psi).
  - Staple your solution set.
- **Submission of work:** Submit your on-time solution sets and project reports to the CE 131L IN box in Room 118 Hudson. Do not submit your work to the TA. If your homework or project is late, or if you have an extension, submit it to me after class or in my office.
- **Late work:** Grades for solutions to assignments turned in after the time they are due will be penalized ten points for each day late; late penalties are not accrued for weekends or University holidays. For example, if you submit your homework solution before 5:00 on the Monday after a 5:00 Friday due-date, the grade will be penalized 10 points. Assignments submitted after the the solution is posted get no credit. Submit late work to me or under my office door.
- **Grading:** The TA will grade each homework assignment out of 100 points.
- **Graded homework and answer keys:** Graded homework will be placed in the CE 131L OUT box in Room 118 Hudson. Homework answer keys will be posted outside my office door when graded homework solution sets are returned.

COURSE SCHEDULE

Week	Dates	Topic	Reading
1	8/30 9/1	strain energy, Castigliano's theorems, superposition, examples;	hand out
		flexibility (force) method and stiffness (displacement) method; linearity;	Ch. 1-2
	due 9/9	HW 1: 2.9, 2.20, and hand-out problems	hand out
2	9/6 9/8	meaning of flexibility matrix coefficients; introduction to stiffness methods;	hand out
		Maxwell reciprocity experiment and hypothesis test.	hand out
	due 9/16	HW 2: Castigliano theorem problems	hand out
		— PART I. TRUSSES —	
3	9/13 9/15	joints; displacement and reaction coordinates;	3.1-3.5
		truss bar element stiffness matrix in local and global coordinates;	
		truss stiffness matrix assembly methods (element-wise and column-wise);	3.5-3.8
		partitioning $\mathbf{K_s}$ for displacement unknowns and force unknowns	9.1
	due 9/23	HW 3: 3.2, 3.4, 3.7, 3.9, 3.10, 3.14, 3.16, 3.18	
4	9/20 9/22	examples;	3.5-3.8, 9.4
		Matlab implementation for 2-D trusses.	hand out
5	9/27 9/29	geometric stiffness effects in 2-D trusses.	hand out
		3-D trusses.	8.1, hand out
	due 10/7	HW 4: Matlab implementation for geometric stiffness in trusses	
6	** 10/4 **	TEST 1 - The Matrix Stiffness Method for Plane Trusses	
		— PART II. BEAMS —	
	10/6	element and structural coordinates;	5.1-5.2
		shear deformation effects in beam elements;	hand out
		beam element stiffness matrix and column-wise assembly;	5.4-5.5
	due 10/14	HW 5: 5.6, 5.10, 5.14, 5.20, 5.25	
7	10/11	*Fall Recess*	
	10/13	superposition, fixed end forces, and equivalent load vector;	5.5-5.7
		joint deflections, reactions, and internal forces;	
		beam element end forces, shear and moment diagrams;	
	10/13	examples of matrix methods for beam problems	
	due 10/21	HW 6: 5.29, 5.33	
8	10/18 10/20	examples of matrix methods for beam problems	
		Matlab implementation for continuous beams	hand out
		eigen-values and eigen-vectors of stiffness matrices	hand out, 9.9
	due 10/28	HW 7: Matlab analyses for 2-D beams	
		— PART III. FRAMES —	
9	10/25 10/27	frame element stiffness matrix in local and global coordinates;	6.1-6.4
		stiffness matrix assembly, fixed-end forces, equivalent load vector,	
		deflections, reactions, and internal forces; temperature effects	
		examples of frames with vertical and horizontal beams	9.2
10	** 11/1 **	TEST 2 - The Matrix Stiffness Method for Beams	6.5-6.6
	11/3	examples of frames with inclined beams:	
	due 11/4	HW 8: 6.8, 6.14, 6.17, 6.25, 6.33, 6.49	
11	11/8 11/10	Matlab implementation for 2-D frames	hand out
		2D frame element geometric stiffness matrix	hand out
		3D frames, coordinate transformations, and the Frame3DD program	8.3
	due 11/11	HW 9: Matlab implementation for 2-D frames	
	due 11/18	HW 10: 8.3, 8.4, 8.12, 8.15 using the Frame3DD program	
		— PART IV. STRUCTURAL DYNAMICS AND BUCKLING —	
12	11/15 11/17	review of single degree of freedom oscillations	hand out
		multi-degree of freedom systems and the generalized eigen-value problem	
13	11/22	natural frequencies, mode shapes, proportional damping	hand out
	11/24	*Thanksgiving Recess*	
	due 12/2	HW 11: WEAVE exercises	
14	** 11/29 **	TEST 3 - The Matrix Stiffness Method for Frames	
	12/1	matrix condensation, shear, temperature, connections	9.3,9.5-9.7
15	12/6 12/8	buckling of 2D and 3D frames	hand out
	** 12/13 **	*** THE TAKE HOME FINAL IS DUE AT 12:00 PM (NOON) ***	

REFERENCES

Bostok Library Call Numbers: 624.17, 624.171.

1. Allen, H.G., and Bulson, P.S., *Background to Buckling,* McGraw-Hill, 1980. ⋆
2. Arbabi, F. *Structural Analysis and Behavior,* McGraw-Hill, 1991.
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4. Gaylord, Jr., E.H., *Structural Engineering Handbook, 3rd ed.,* McGraw-Hill, 1990.
5. Gerstle, K.H., *Basic Structural Analysis,* Prentice-Hall, 1974.
6. Hibbler, R.C., *Structural Analysis,* 5th ed., Prentice-Hall, 2002.
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8. Ketter, R.L., Lee, and Prawel, *Structural Analysis and Design,* McGraw-Hill, 1979.
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12. McGuire, W., Gallagher, R.H. and Ziemian, R.D., *Matrix Structural Analysis,* 2nd ed. John Wiley, 2000.
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14. Paz, M. and Leigh, W.E., *Integrated Matrix Analysis of Structures - Theory and Computation,* Kluwer Pub., 2001.
15. Przeminiecki, J.S., *Theory of Matrix Structural Analysis,* Dover Press, 1985. ⋆
16. Sack, R.L., *Matrix Structural Analysis,* Waveland Press, 1994. ⋆
17. Sennet, R.E., *Matrix Analysis of Structures,* Waveland Press, 2000.
18. Wang, C-K, *Matrix Methods of Structural Analysis,* International Textbook Co., 1970.