INTERMEDIATE MECHANICS OF DEFORMABLE BODIES
(58:150/51:151/53:140)

Fall 2003

Instructor: Sharif Rahman, 2140 SC, 335-5679, rahman@engineering.uiowa.edu

Lecture: WF, 3:30 – 4:45 pm at 3315 SC

Office Hours: WF, 1:00 – 2:30 pm at 2140 SC + by appointment

Prerequisites: 57:019

Textbooks:

1. A. C. Ugural and S. K. Fenster, Advanced Strength and Applied Elasticity, 4th Edition, Prentice Hall PTR, Upper Saddle River, New Jersey, 2003. (Available at IMU Bookstore, 335-3179.)

2. S. Rahman, Lecture Notes, 2003. (Available at IMU Bookstore.)

References:

1. A. P. Boresi and K. P. Chong, Elasticity in Engineering Mechanics, 2nd Edition, John Wiley, 2000.

2. S. P. Timoshenko and J. N. Goodier, Theory of Elasticity, 3rd Edition, Mc-Graw Hill, 1970.

3. I. S. Sokolnikoff, Mathematical Theory of Elasticity, 2nd Edition, Mc-Graw Hill, 1956.

4. M. Hetenyi, Beams on Elastic Foundations, The University of Michigan Press, London, 1946.

5. H. L. Langhaar, Energy Methods in Applied Mechanics, John Wiley, 1962.

TA: Dong Wei, 248 ERF, 335-6394, dwei@engineering.uiowa.edu
TA Office Hours: T,Thu; 10:30 am – 12:00 noon at G130 SC

Course Goals: This course provides students with the opportunity to develop an understanding of the basic scientific principles, techniques, and procedures used to derive the critical load-stress and load-deformation relationships that govern the behavior of deformable bodies in equilibrium, and to apply this basic knowledge in the solution of typical engineering problems arising in the mechanical design and analysis of deformable systems.

Course Objectives

1. Students will have an understanding of stress, strain, and constitutive relationship in mechanical and structural systems.

2. Students will be able to solve two-dimensional elasticity problems arising in design and analysis of deformable bodies subject to mechanical, thermal, and contact stresses.

3. Students will have the knowledge of material failure criteria and will be able to derive critical load-stress and load-deformation relationships in mechanical and structural systems.

4. Students will have an understanding of both elementary and elasticity theories of beams and will be able to solve for stress, strain, and displacements in a straight or a curved beam.

5. Students will be able to solve engineering problems in mechanical systems involving bars under torsion, axisymmetric stress state, and beams on elastic foundation.

6. Students will understand energy methods in elasticity and will be able to solve both statically determinate and indeterminate problems of mechanical systems using energy based theorems and principles.

Course Outline (30 Meetings)

1. Stress Analysis (4 lectures)

- Introduction, historical perspectives, fundamental assumption of continuity
- Definition of stress
- Components of stress (stress tensor)
- Variation of stress within a body
- Two-dimensional stress at a point
- Principal stresses and Maximum shear stress in 2D
- Mohr's circle for 2D stress
- Three-dimensional stress at a point
- Principal stress in 3D
- Normal and shear stress in oblique plane
- Octahedral stresses
- Mohr's circle for 3D stress
- Boundary conditions

2. Strain Analysis and Constitutive Equations (4 lectures)

- Introduction, displacements in a body
- Deformation
- Strain
- Compatibility equation
- State of strain at a point, transformation of strain, Mohr's circle for strain
- principal strain, maximum shear strain, octahedral strain
- Strain measurements
- Engineering materials
- Hooke's law and Generalized Hooke's law
- Strain energy
- Strain energy in common structural components, strain energy components
- Saint-Venant's principle

3. 2D Problems in Elasticity (3 lectures)

- Introduction, fundamental principles in theory of elasticity
- Plane stress and plane strain
- Stress function
- Solution of elasticity problems
- Basic relations in polar coordinates
- Stresses due to concentrated loads
- Stress concentration
- Thermal stresses
- Contact stresses

4. Material Failure Criteria (2 lectures)

- Introduction
- Yielding failure, fracture failure
- Yield criteria for pressure-independent material
- Maximum shear stress theory
- Maximum distortion energy theory
- Octahedral shear stress theory
- Comparison of yielding theories
- Maximum principal stress theory
- Yield criteria for pressure-dependent material
- Coulomb-Mohr theory
- Drucker-Prager theory
- Failure criteria for metal fatigue
- Fatigue life under combined loads
- Impact and dynamic loads
- Dynamic and thermal effects

5. Bending of Beams (5 lectures)

- Introduction
- Pure bending of beams of symmetrical cross-section
- Pure bending of beams of asymmetrical cross-section
- Bending of cantilever of narrow section
- Bending of simply supported narrow beam
- Elementary theory of bending
- Bending and shear stresses
- Effect of transverse normal stress
- Statically indeterminate systems
- Energy method for deflections
- Exact solution
- Winkler's theory

6. Torsion of Bars (2 lectures)

- Introduction
- Elementary theory of torsion of circular bars
- General solution of torsion problem
- Prandtl's membrane analogy
- Torsion of thin-walled members of open cross-section
- Torsion of multiply connected thin-walled sections
- Fluid flow analogy
- Torsion of restrained thin-walled members of open cross-section

7. Axisymmetric Problems (2 lectures)

- Introduction
- Thick-walled cylinders
- Maximum tangential stress
- Application of failure theories
- Compound cylinders
- Rotating disks of constant thickness
- Rotating disks of variable thickness
- Rotating disks of uniform stress
- Thermal stresses in thin disks

8. Beams on Elastic Foundation (2 lectures)

- Introduction
- Infinite beams
- Semi-infinite beams
- Finite beams
- Beams supported by equally spaced elastic elements
- Simplified solutions for relatively stiff beams
- Applications

9. Energy Methods (2 lectures)

- Introduction
- Work done in deformation
- Reciprocity theorem
- Castigliano's theorem
- Unit or dummy load method
- Crotti-Engesser Theorem
- Statically Indeterminate Systems
- Principle of virtual work
- Trigonometric series
- Rayleigh-Ritz method

+ **[1 Midterm Examination]**
+ **[2 Review Sessions]**
+ **[1 Class Discussion]**

Performance Evaluation Criteria

A. Homework Assignments

- The assigned homework problems should be worked out and submitted to the instructor in a professional format at the beginning of the lecture period. Include your name, course title, assigned homework problem numbers in the heading of your paper. The dates of assignments and their due dates are given in the attached assignment sheet (Page 4).

- Your homework solution must be submitted individually. No group submission or copies are permitted. However, discussion with the fellow students is permitted. Also, you are advised to obtain help from the instructor and/or TA when needed.

- Homework solution will be posted at:
  `http://www.engineering.uiowa.edu/~deform`

B. Examination Policy

- There will be two examinations in this course. One is the midterm examination and the other is the final examination. Both will be closed-book examinations. The schedules for these examinations will be announced in the class.

- If any of these examinations is missed, the instructor will use his discretion in choosing alternative means to evaluate student's performance. This can be a make-up examination, oral examination, or both.

C. Grading Policy

- The letter grade for this course will be based on the student's overall performance on homework assignments, the midterm examination, and the final examination.

- The distribution of points is as follows:

  1. Homework Assignments 30 percent
  2. Midterm Examination 30 percent
  3. Final Examination 40 percent

- The final grade will be posted at:
  `http://www.engineering.uiowa.edu/~deform`

Assignment Sheet
58:150 Intermediate Mechanics of Deformable Bodies
Fall 2003

A. C. Ugural and S. K. Fenster, Advanced Strength and Applied Elasticity, 4th Edition, Prentice Hall PTR, Upper Saddle River, New Jersey, 2003.

Wk.	No.	Date	Topics	Reading[(a)]	Homework	Due Date
1	1	Aug 27, Wed	Stress Analysis	1.1-1.4, 1.8		
	2	Aug 29, Fri		1.9-1.11		
2	3	Sep 03, Wed		1.12,1.13	HW #1	Sep 10, Wed
	4	Sep 05, Fri		1.14-1.16		
3	5	Sep 10, Wed	Strain & Constitutive Eqn.	2.1-2.4	HW #2	Sep 17, Wed
	6	Sep 12, Fri		2.5, 2.10		
4	7	Sep 17, Wed		2.6-2.9	HW #3	Sep 24, Wed
	8	Sep 19, Fri		2.11-2.14		
5	9	Sep 24, Wed	2D Elasticity Problems	3.1-3.6	HW #4	Oct 01, Wed
	10	Sep 26, Fri		3.8,3.9,3.11		
6	11	Oct 01, Wed		3.7.3.13	HW #5	Oct 08, Wed
	12	Oct 03, Fri	Failure Criteria	4.1-4.10		
7	13	Oct 08, Wed		4.11-4.17	HW #6	Oct 22, Wed
	14	Oct 10, Fri	*Review*			
8	15	Oct 15, Wed	**Midterm Examination**			
	16	Oct 17, Fri	*Class Discussion*			
9	17	Oct 22, Wed	Bending of Beams	5.1-5.3		
	18	Oct 24, Fri		5.4,5.5		
10	19	Oct 29, Wed		5.6-5.8,5.10	HW #7	Nov 05, Wed
	20	Oct 31, Fri		5.11,5.12		
11	21	Nov 05, Wed		5.13-5.15	HW #8	Nov 12, Wed
	22	Nov 07, Fri	Torsion of Bars	6.1-6.5		
12	23	Nov 12, Wed		6.6-6.9	HW #9	Nov 19, Wed
	24	Nov 14, Fri	Axisymmetric Problems	8.1-8.5		
13	25	Nov 19, Wed		8.6-8.10	HW #10	Dec 03, Wed
	26	Nov 21, Fri	Beams on Elastic Found.	9.1-9.4		
14	27	Dec 03, Wed		9.5-9.7,9.9	HW #11	Dec 10, Wed
	28	Dec 05, Fri	Energy Methods	10.1-10.7		
15	29	Dec 10, Wed		10.8-10.11	HW #12	Dec 15, Mon
	30	Dec 12, Fri	*Review/ACE Evaluation*			

(a) section no. of textbook