

Outline
Mechanics of Materials-2
MEC-402

Task

In this second part we mainly study Beam deflections, Combined loading, Columns, and Energy Methods. You are required to work through the textbook and solve the Practice Problems, the Assignments must be submitted, and the Exam Preparation Set should be attempted to get ready for the exams.

Text and Reference

Several quality books are available for Mechanics of Materials. Some of the recommended textbooks and references are as follows:

- a. Strength of Materials (9e) – Barry J. Goodno
- b. Mechanics of Materials (7e) – Ferdinand P. Beer, E. Russell Johnston Jr., John DeWolf, and David F. Mazurek
- c. Mechanics of Materials (9e) – Russell C. Hibbeler
- d. Engineering Mechanics of Solids (2e) – Egor P. Popov
- e. Strength of Materials (3e SI) - G. H. Ryder
- f. Mechanics of Materials – Ansel. C. Ugural
- g. Mechanics of Materials – William F. Riley, Leroy D. Sturges, and Don H. Morris
- h. Mechanics of Materials – Anthony Bedford, Kenneth M. Liechti
- i. Schaum Outline of Strength of Materials (4e) - William A. Nash
- j. Advanced Mechanics of Materials (6e) – Arthur P. Boresi & Richard J. Schmidt
- k. Advanced Mechanics of Materials and Applied Elasticity (6e) - Ansel C. Ugural, and Saul K. Fenster
- l. Advanced Mechanics of Materials – Robert Cook, and Warren Young
- m. Advanced Mechanics of Materials - William B. Bickford
- n. Mechanical Behavior of Materials (3e) – Norman E. Dowling

Worksheet 1 : Multiaxial Loading
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Topics

- Stress and Strain Transformations, Mohr Circles, Strain gages
 - Failure Theories and Combined loading
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Practice Problems

Problem 1 *Transformation of stress.* Consider a welded rectangular plate with the weld making an angle of 100° with the base. The applied loads are such that the plate is in a homogeneous state of two-dimensional stress relative to the $x-y$ axes of

$$\begin{bmatrix} 100 & 50 \\ 50 & 20 \end{bmatrix} \text{ ksi.}$$

Find the state of stress in the plate relative to the set of axes aligned with the weld.

Problem 2 *Principal stresses.* Given a state of stress

$$\begin{bmatrix} 1 & 10 \\ 10 & 3 \end{bmatrix} \text{ MPa}$$

find the principal values and principal directions.

Problem 3 *Mohr's circle.* Consider the two-dimensional state of stress given below

$$\begin{bmatrix} 3 & 6 \\ 6 & 0 \end{bmatrix} \text{ MPa.}$$

Using Mohr's circle find the principal values, the principal angle, the maximum shear, and the maximum shear angle. Sketch the principal stresses on a properly oriented element. Also sketch the maximum shear state on a properly oriented element.

Problem 4 *Mohr's circle for torsion.* Consider the two-dimensional state of stress on the surface of an elastic circular bar of radius r , polar moment of inertia J , in torsion with an applied torque T :

$$\begin{bmatrix} 0 & Tr/J \\ Tr/J & 0 \end{bmatrix} \text{ MPa}$$

Draw the Mohr's circle and determine the principal stresses. Sketch them on a properly oriented element.

Problem 5 *Three-dimensional Mohr's circles.* Consider the state of stress:

$$\begin{bmatrix} 2 & 0 & 1 \\ 0 & -2 & 0 \\ 1 & 0 & 0 \end{bmatrix} \text{ MPa}$$

Draw the Mohr's circle and determine the principal stresses. Sketch them on a properly oriented element.

Problem 6 *Mohr's circle for strain.* Consider a two-dimensional state of pure shear $\gamma_{xy} = 200\mu$

and $\epsilon_x = \epsilon_y = 0$. Sketch the deformation associated with this strain state for a homogeneously strained square of material that is aligned with the x - y coordinate axes. Compute the principal strains and sketch the deformation associated with this strain state for a homogeneously strained square of material which is aligned with the principal axes.

Problem 7 *Strain rosette.* Given the normal strains in a strain rosette laid out in a 0° - 45° - 90° configuration. Determine the two-dimensional state of strain.

Problem 8 *Elastic constants.* Use energy argument to show $G = \frac{E}{2(1+\nu)}$

Problem 9 *Tresca's Condition.* Consider the state of stress:

$$\begin{bmatrix} 2 & 0 & 1 \\ 0 & -2 & 0 \\ 1 & 0 & 0 \end{bmatrix} \text{ MPa}$$

Here k is a scaling factor. if $\tau_Y = 20$ ksi, what value of k causes yield.

Problem 10 *Calibration of τ_Y .* The typical test for calibrating yield criteria is to use a uniaxial tension test to determine the yield stress σ_Y . What is the relation between σ_Y and τ_Y ?

Problem 11 *Thin walled tube in axial and torsional loading..* Consider a thin walled tube of inner radius r and thickness t . A tensile load of P is applied along its axis. In addition a torque of T is also applied. Determine the limits on P and T on the combined state of loading according to the von Mises condition.

Problem 12 *Thin walled pressure vessel.* Consider a thin walled cylindrical pressure vessel of inner radius r and thickness t . Determine how much pressure p can be applied before yield takes place according von Mises condition.

Problem 13 *Relation between σ_Y and τ_Y according to von Mises condition.* Consider an experiment that produces a state of yield in pure shear. Find the relation between a measured yield stress τ_Y , in shear and normal yield stress σ_Y , in tension.

Assignments

Assignment 1. Following the outline in Popov, derive the transformation of stresses in two dimensional problems. In addition show that the transformation relations can be written in the form of a circle.[10]

Assignment 2. Derive the expression for the maximum distortional energy theory. Start with $U_o = U_{ov} + U_{od}$, where U_o is the total strain energy density. U_{ov} and U_{od} are the volumetric and distortional strain energy densities respectively.[10]

Exam Preparation

Preparation Set Attempt unsolved back of chapter problems of the relevant chapter.

Worksheet 2 : Beam Deflection
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Practice Problems

Problem 1 *End loaded Cantilever beam.* Consider a Cantilever beam of length L . It is end loaded with a concentrated load of P . Compute the deflection $v(x)$.

Problem 2 *Cantilever beam with two point loads.* Consider a Cantilever beam of length L . It is loaded with concentrated load of P at L and with P at $L/2$. Compute the deflection $v(x)$.

Problem 3 *Displacement based beam selection.* Consider simply supported beam of length L that is to carry a uniform load of w_o (force per length) with a maximum allowed deflection of Δ_{max} . Determine a formula for the required moment of inertia I of the cross-section.

Problem 4 *Boundary conditions and distributed loads.* Below are shown a number of beams with a variety of loadings and boundary conditions. For each beam state the distributed load function and boundary conditions.

Assignments

Assignment 3. Write a detailed note on singularity functions as they are used to find the deflection of beams.[10]

Exam Preparation

Preparation Set Attempt unsolved back of chapter problems of the relevant chapter.

Worksheet 3 : Buckling
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Practice Problems

Problem 1 *Multiple rigid links and springs.* Consider a system composed of two rigid links connected to each other by a pin and torsional spring. One of the links is also connected to a rigid floor by a pin and torsinal spring. The length of each link is L . The system is end loaded with a concentrated load of P . What is the buckling load for the system?

Problem 2 *Pin-pin column.* Consider a pin-pin column of length L . It is loaded with a concentrated compressive load of P . Determine the critical buckling load.

Problem 3 *Pin-clamped column.* Consider a pin-clamped column of length L . It is loaded with a concentrated compressive load of P . Determine the critical buckling load.

Problem 4,5 *Clamped-free beam-column buckling.* Consider a beam-column of length L . It is built-in at one end and free from kinematic boundary conditions at the other. The system is subjected to an axial compressive load P . Find the system's critical load.

Problem 6 *Clamped-free beam-column with mid-span spring support.* Consider a clamped-free beam-column, but now with a lateral spring support at mid-span. Determine the buckling load for this system.

Problem 7 *Buckling due to self-weight.* Consider a tall narrow tree loaded only by gravity. For a given material density and effective crosssectional area, determine how tall the tree can be before it buckles under its own weight. For simplicity, assume the cross-sectional area, A , the Young's modulus, E , and the second moment of the area, I , to all be constants.

Assignments

Assignment 4 Derive the critial load expressions for the following end conditions: (a) pin-pin, (b) fixed-fixed, (c) pin-fixed, and (d) fixed-free. What are the effective lengths for each case.[10]

Assignment 5 Derive the secant formula for the eccentrically loaded column.[10]

Exam Preparation

Preparation Set Attempt unsolved back of chapter problems of the relevant chapter.

Worksheet 4 : Energy Methods
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Topics

- a. Virtual Force Method
 - b. Potential Energy Method
 - c. Virtual Displacement Method
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Practice Problems

Problem 1 Axially loaded rod. Consider the rod shown figure 1, determine using the principle of virtual forces the displacement at $x = a$.

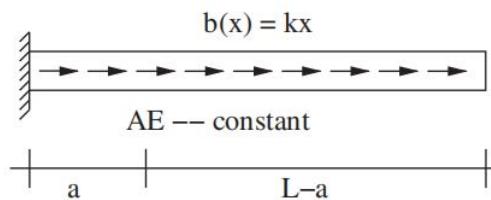


Figure 1 Bar

Problem 2 Torsion of shaft. Consider the torsion rod shown in figure 2, using the principle of virtual moments, determine the rotation at $z = b$.

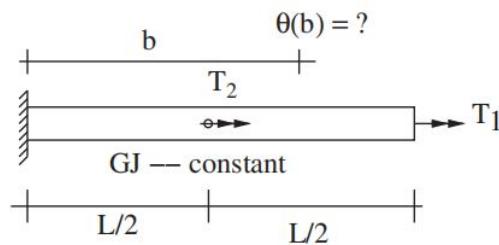


Figure 2 Shaft

Problem 3 Bending of a beam. Consider the beam shown figure 3, using the principle of virtual forces, determine the tip displacement, Δ .

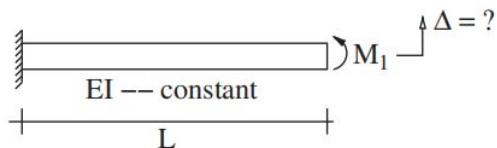


Figure 3 Beam

Problem 4 A shear beam. Consider the beam shown in figure 4. Determine using the principle of virtual forces the tip displacement due to direct shear and bending, Δ .

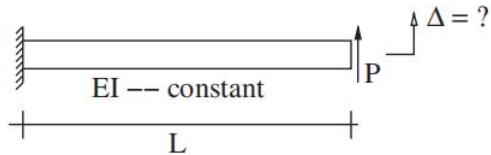


Figure 4 Shear Beam

Problem 5

Problem 6

Problem 7

Problem 8

Problem 9 Bar with two axial forces. For the bar shown in figure 5, determine the relation between the applied forces (P_1 and P_2) and the resulting displacements (Δ_1 and Δ_2).

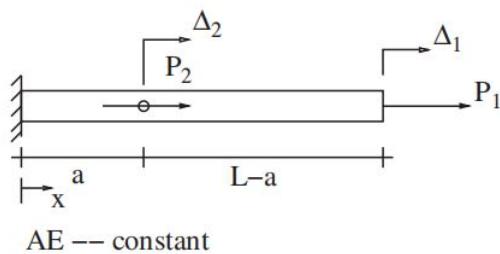


Figure 5 Bar Two Forces

Problem 10 Statically indeterminate rod with a point torque. For the rod shown in figure 6 determine the relation between the applied torque, T_1 , and the resulting rotation at the point of application, θ_1 .

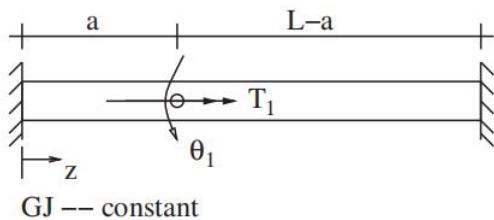


Figure 6 Rod point Torque

Assignments

Assignment 4 .[10]

Assignment 5 .[10]

Exam Preparation

Preparation Set Attempt unsolved back of chapter problems of the relevant chapter.