ME 302 Materials Mechanics

Introduction and Overview

This is a fundamental course in all Civil and Mechanical Engineering Programs.

Sometimes it is called:

“Strength of Materials” or “Mechanics of Materials”

CEE 370 Engineering Mechanics of Deformable Bodies

The Civil Engineering Department is offering their own Mechanics of Materials Course.

All Civil Engineering majors or pre-CEE majors should drop ME 302 and sign up for CEE 370.

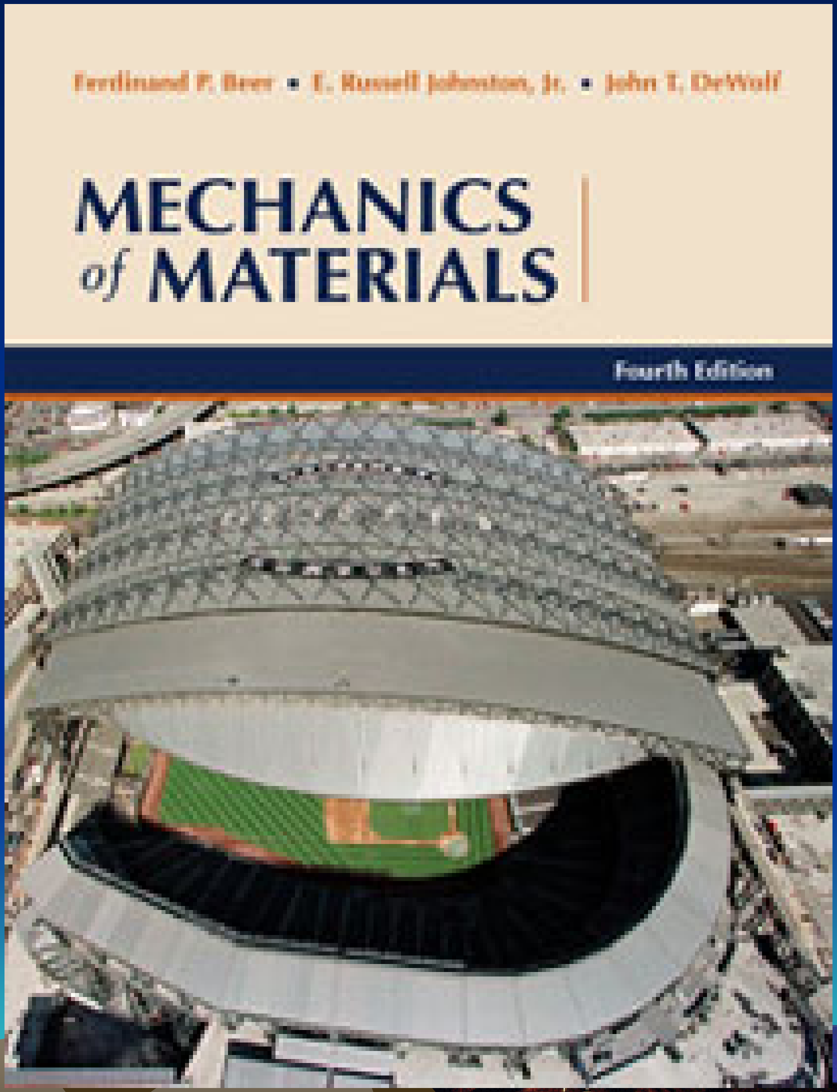
CEE 370 meets in CBC C-120

11:30 AM – 12:45 PM

Instructor: Prof. Aly Said

Course Material

- Lectures & Notes
- Text Book
- Website
- Email



Instructor: Dr. Brendan J. O'Toole, Ph.D.

Professor: Brendan J. O'Toole, Ph.D.

Office: TBE B122

Phone: 895-3885

E-Mail: bj@me.unlv.edu

Days/Time/Room: TR / 11:30 AM – 12:45 PM / MPE 232

Text: "Mechanics of Materials", 4th Edition
Beer, Johnston, & DeWolf
McGraw Hill, 2006

O'Toole Website: http://www.egr.unlv.edu/~bj/

Prerequisites:
EGG 206 Engineering Mechanics I (Statics)
MAT 182 Calculus II
PHY 180 Physics I
EGG (MEG) 100 Intro. to Engineering Design

Instructor: Dr. Brendan J. O'Toole

- **Education**
  - **Ph.D. & M.S. in Mechanical Engineering,** University of Delaware, Newark, DE, 1993 & 1989.
  - **B.S. in Mechanical and Aerospace Engineering,** University of Delaware, 1986.
- **Employment**
  - **Associate Professor** - Mechanical Engineering, UNLV (8/92 - present)
    - Areas of interest:
      - Experimental and computational solid mechanics
      - Structural Dynamics, Finite Element Analysis, and Design
      - Fabrication of components and structures (emphasis on composites)
      - Mechanics of solid cellular foams: dynamic & static properties
  - **Director** – Center for Materials and Structures (CMS)
    University of Nevada Las Vegas (12/05 - present)
  - **Program Manager** – Soldiers Future Force Electronics Reliability and Survivability Technology Program, UNLV/U.S. Army Research Laboratory Cooperative Agreement
  - **Director of Engineering** – High Pressure Science and Engineering Center
    University of Nevada Las Vegas (1/03 - present)
  - **Visiting Research Associate** - Composites and Lightweight Structures Branch
    U.S. Army Research Laboratory, Aberdeen MD (10/01 - 4/02)
    - Computational simulation of composite armor systems under ballistic impact loading.

Active Projects for Dr. Brendan J. O’Toole

- Development of a Reconfigurable Tooling System, 2Phase Technologies, Inc.
- Development of Nano-Fiber Reinforced Polyurethane Foams, Department of Energy Stockpile Stewardship Program
- Soldier FERST - Soldier’s Objective Force Electronics Reliability and Survivability Technology Program, US Army
  - Ballistic Shock Propagation Through Structural Joints
  - High Frequency Shock Mitigation in Air Gun Experiments
- Design/Education Oriented Projects
  - Human Powered Vehicle Design, ASME Competition
  - Developing a Balloon Satellite Program, NASA Space Grant/EPSCoR Program
  - High School First Robotics Competition, NASA Space Grant/EPSCoR Program
- Composite Blast Containment Vessels, Sandia National Laboratories
- Blast Loading on Vehicle Structures, DOD EPSCoR and UNLV

MEG 302 Course Objectives

- **Learn the Vocabulary**
- **Improve Your Skill at Drawing Free Body Diagrams**
- **Learn About Material Behavior**
- **Learn How To Solve Mechanics Problems.** This is the largest part of the class. The solution procedure for most mechanics problems involves one or more of the following tasks:
  - A statics analysis of a component to find the internal reactions (forces & moments)
  - Determine stresses and strains in a component based on internal reactions
  - Find the deformation of the component
  - Compare calculated values of stress & deformation with known acceptable values
- **Improve Your Engineering Design Skills**

Vocabulary

This is a sampling of terms that are defined in the text. We will discuss them throughout the semester. You are expected to understand the meaning of these terms. You are also expected to know the correct units for material properties and other variables.

- Rigid Body
- Deformable Body
- Link
- Truss
- Normal Stress
- Shear Stress
- Bearing Stress
- Ultimate Stress
- Yield Stress
- Failure Stress
- Principal Stresses
- Normal Strain
- Shear Strain
- Failure Strain
- Yield Strain

- Shear Modulus
- Poisson's Ratio
- True Stress
- Engineering Stress
- True Strain
- Elastic Behavior
- Plastic Behavior
- Thermal Expansion
- Torsion
- Torque
- Angle of Twist
- Static Indeterminacy
- Power
- Pure Bending
- Area Moment of Inertia
- Polar Moment of Inertia

- Shear Force Diagram
- Bending Moment Diagram
- Transverse Shear
- Cantilever Beam
- Simply Supported Beam
- Clamped Beam
- Isotropic
- Anisotropic
- Homogeneous
- Prismatic
- Thin-Walled Member
- Pressure Vessel
- Combined Loading
- Stress Transformation
- Mohr's Circle
- Plane Stress

- Superposition
- Elastic Curve
- Column
- Buckling
- Euler Buckling
- Plane Strain
- Ductile Behavior
- Brittle Behavior
- Axial Stiffness
- 3-point Bending
- 4-point Bending
- Modulus of Elasticity
- Young's Modulus
- Modulus of Rigidity
- Principal Strains
- Flexural Stiffness

Free Body Diagrams

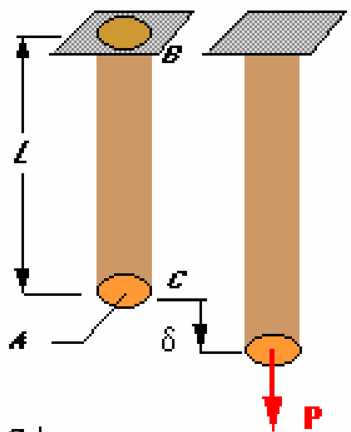
- Free Body Diagrams were first introduced in Physics and Statics courses.
- They are a powerful tool that help define the important loads, reactions, geometry, and coordinate system in a problem so that the correct equilibrium equations are defined and solved.

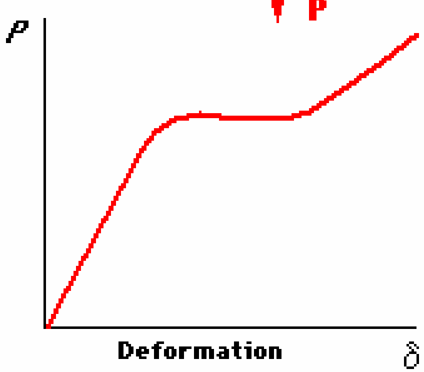
Material Response to Loading

Mechanics of Materials

File   Basic Relationships   Generalized Hooke's Law

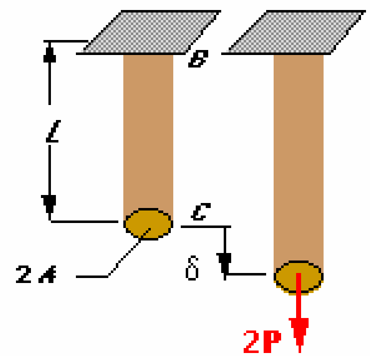
Assume rod *BC* has a length *L* and a uniform cross-sectional area *A*. The rod is suspended from point *B* and a load **P** is applied to end *C*. When the load is applied, the rod elongates an amount δ. Plotting the magnitude *P* of the load against the deformation, we obtain a certain load-deformation diagram.





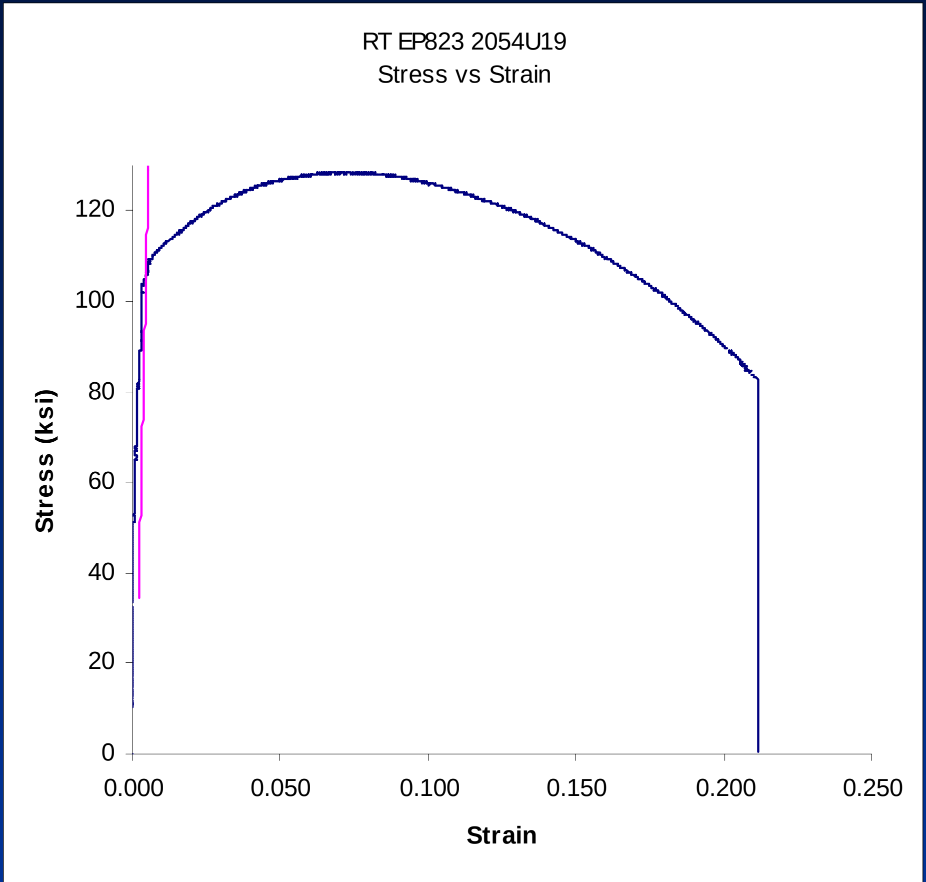
If the cross-sectional area is 2*A*, a load of 2**P** is required to produce the same deformation. In both cases the normal stress is the same: $\sigma = P/A$.

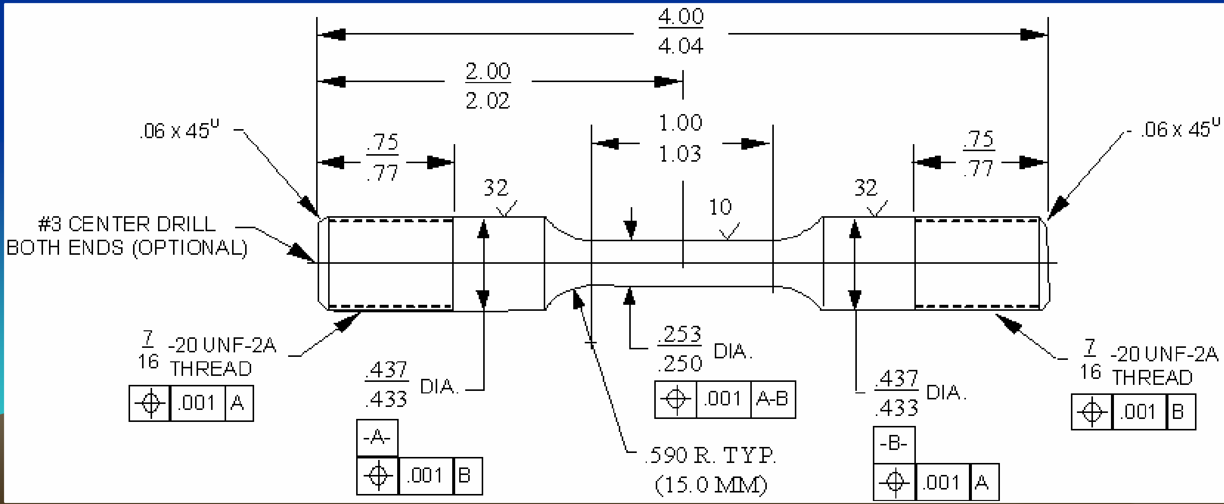
If a load *P* is applied to a rod with a cross-sectional area *A* and length 2*L*, the deformation is 2δ. In either case the ratio of the deformation to the rod length is the same; it is equal to δ / *L*. This observation leads to the concept of normal strain.



$$\varepsilon = \delta / L$$

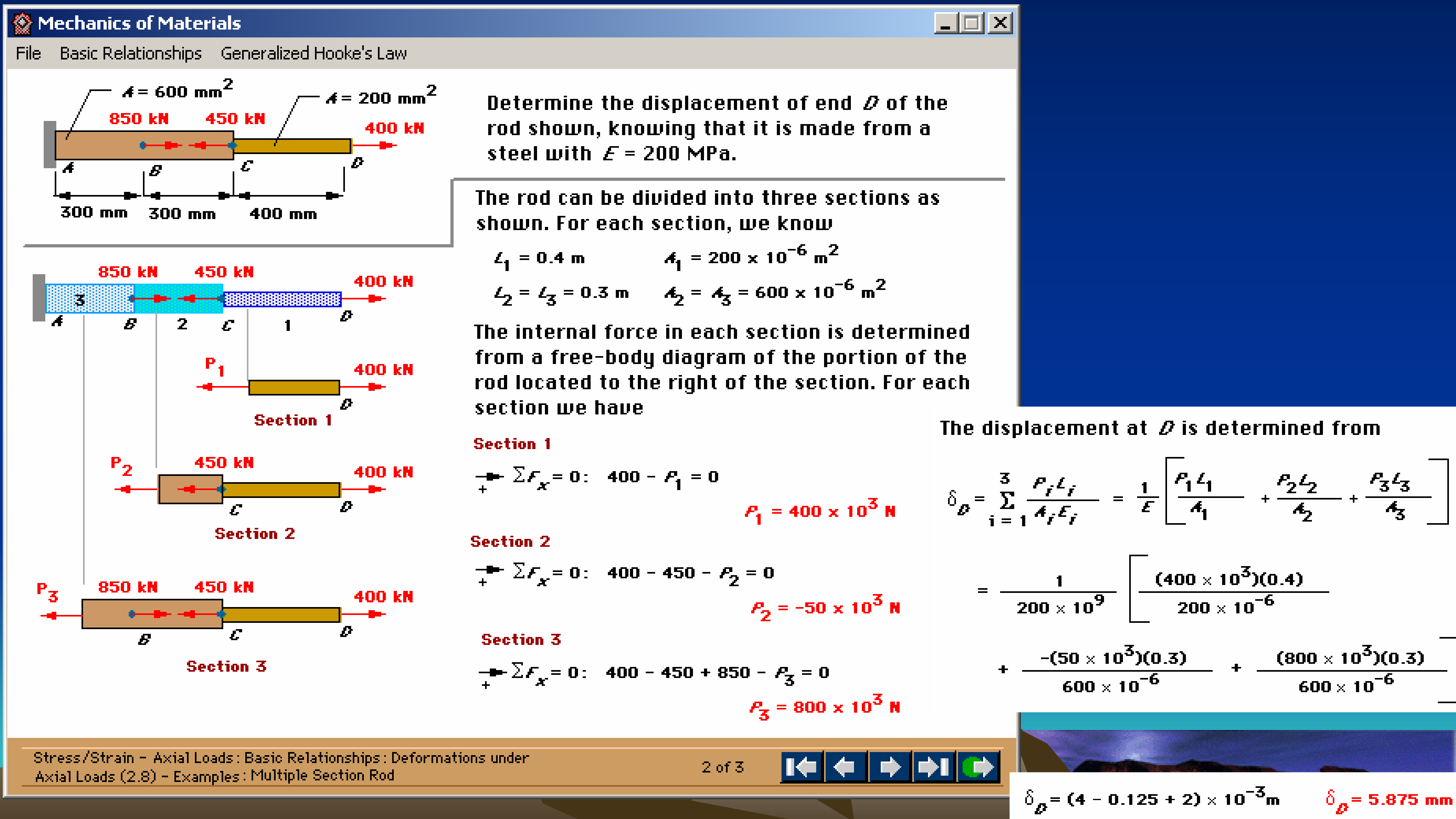
Tensile Test of EP-823 Maraging Steel



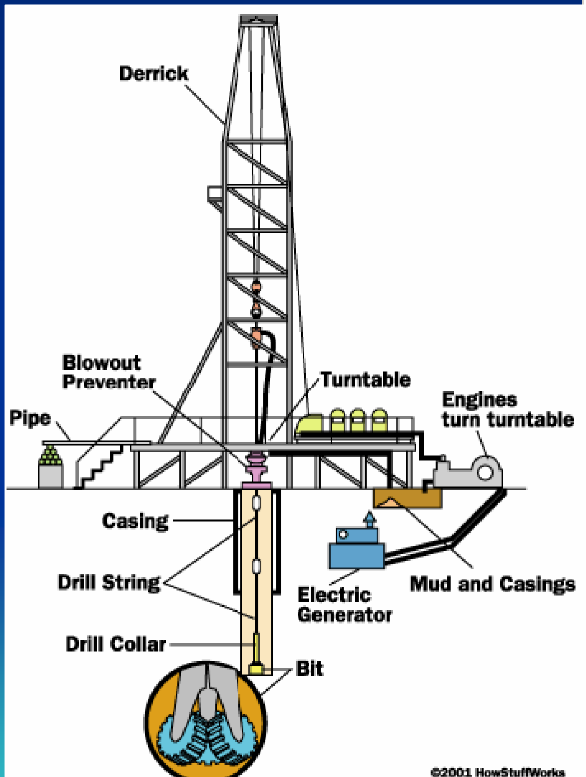


Axial Loading

Example from Software CD included with textbook.



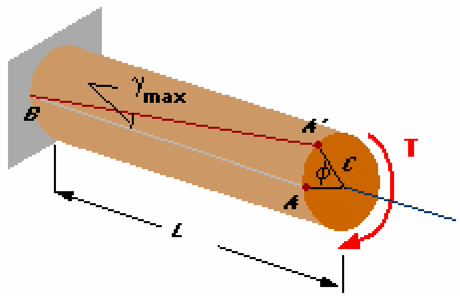
Torsion



Anatomy of an oil rig

Mechanics of Materials

File Circular Shafts Noncircular Members



For a uniform shaft of radius c and length L, it has been shown that the maximum shearing strain γ_{max} is related to the angle of twist ϕ by

$$\gamma_{max} = \frac{c\phi}{L}$$

In addition, the maximum shearing stress is related to the applied torque T by

$$\tau_{max} = \frac{Tc}{J}$$

If the applied torque is not large enough to cause the shearing stress to exceed the yield stress anywhere in the shaft, Hooke's law applies, and $\gamma_{max} = \tau_{max} / G$, so

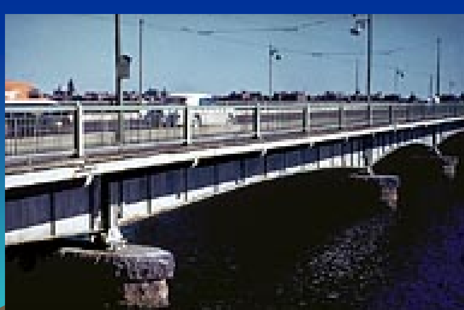
$$\gamma_{max} = \frac{c\phi}{L} = \frac{\tau_{max}}{G} = \frac{Tc}{GJ}$$

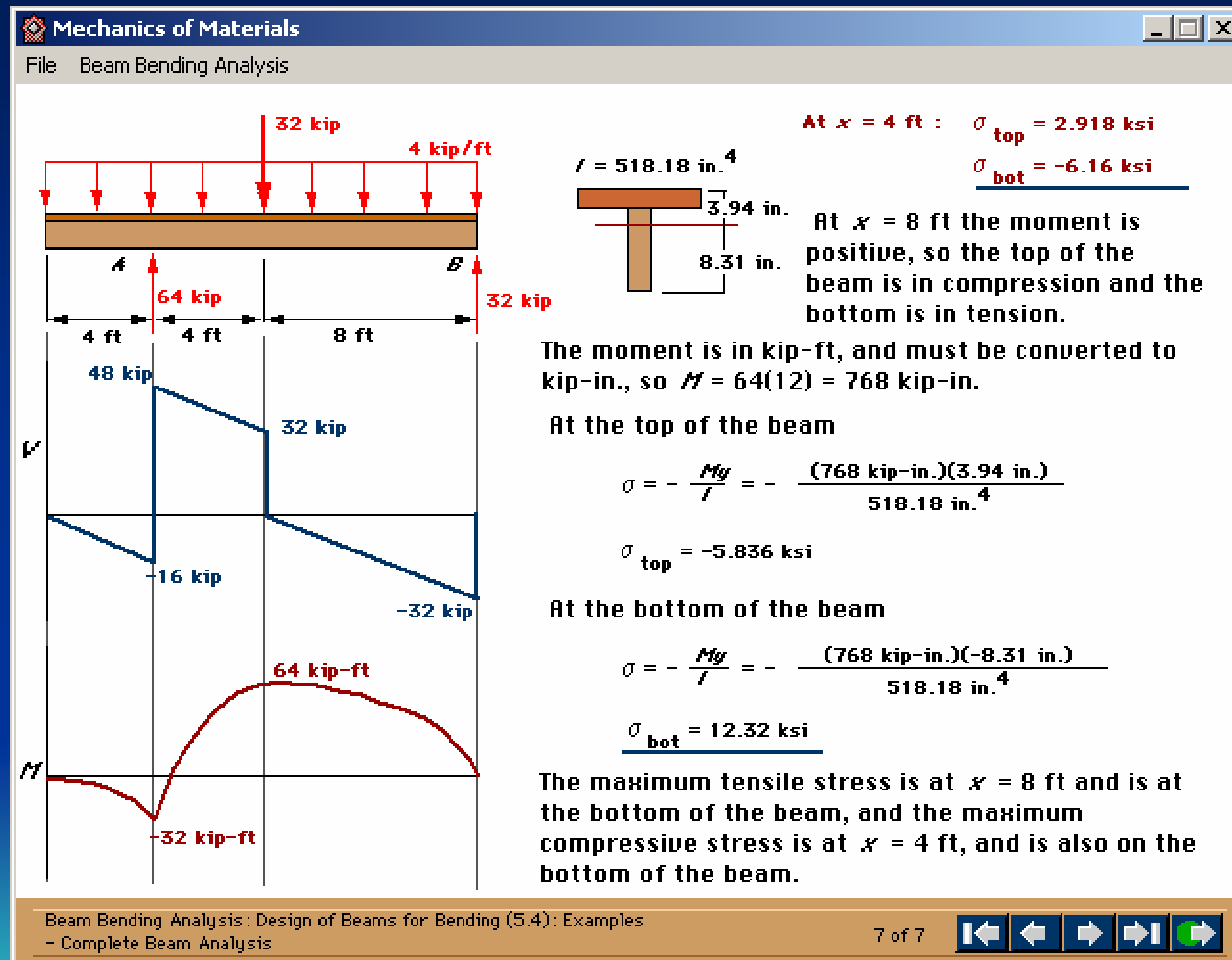
Solving for ϕ,

$$\phi = \frac{TL}{GJ}$$

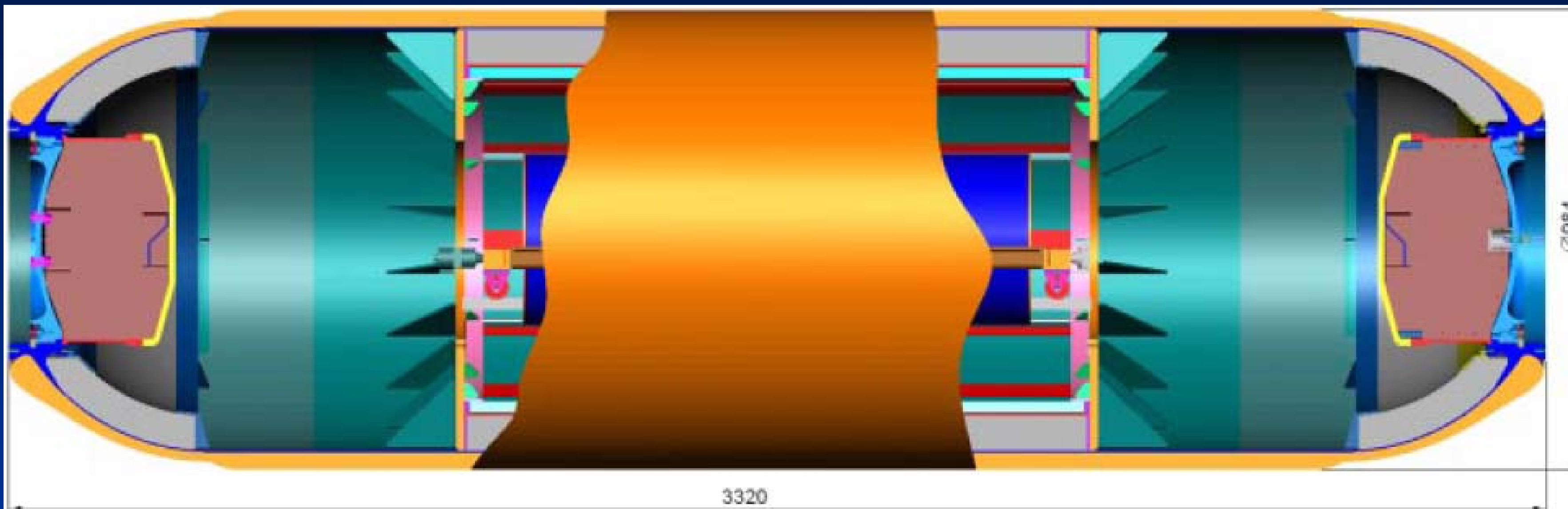
where ϕ is expressed in radians. This relation shows that the angle of twist is proportional to the applied torque (T), shaft length (L), material (G), and geometry (J).

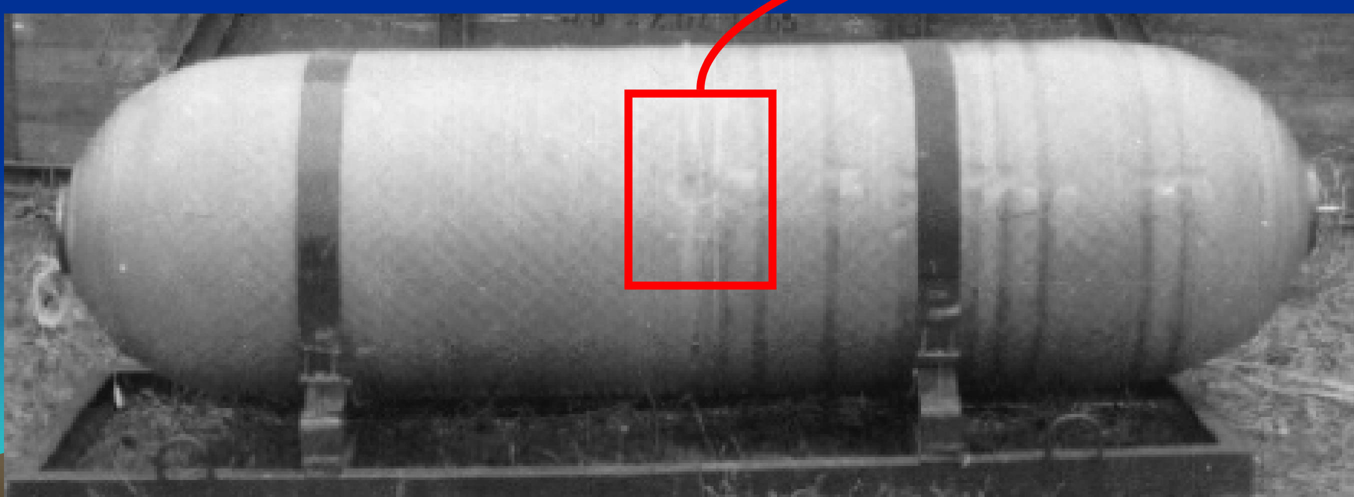
Beams and Bending

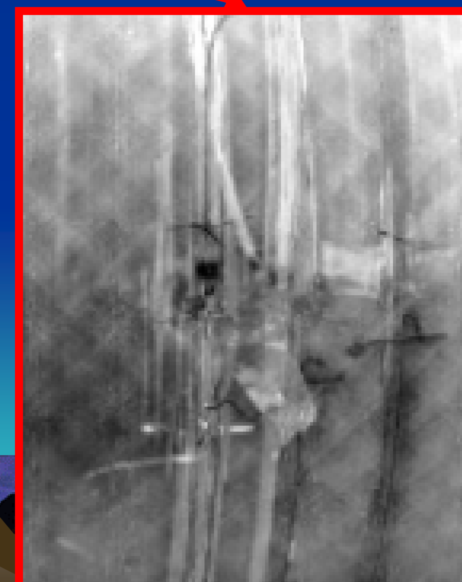




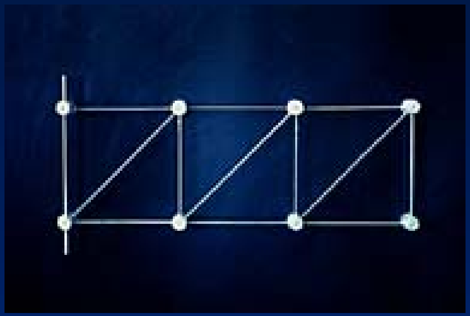
Pressure Vessels & Design

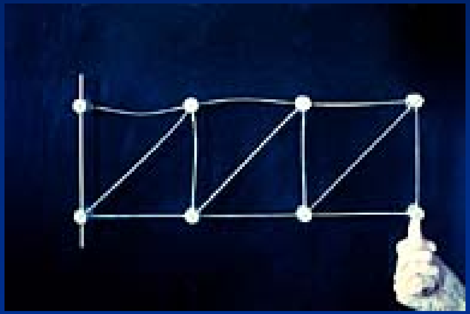


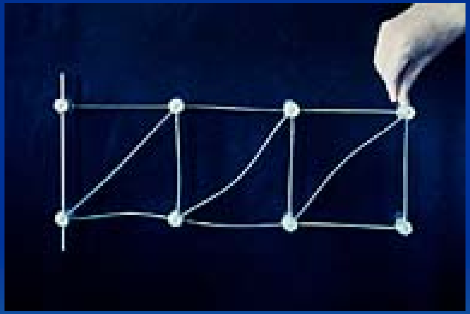


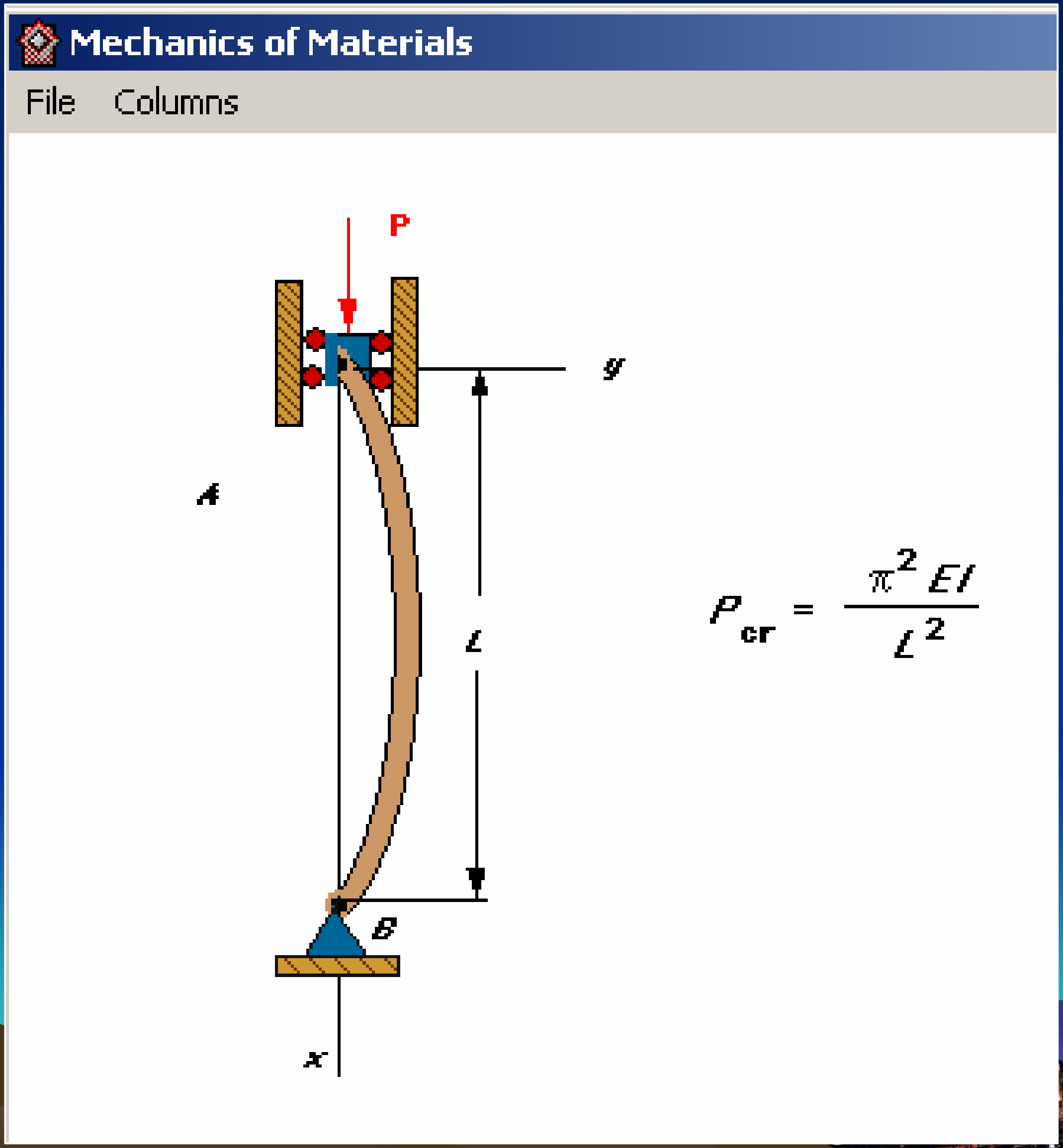


Buckling








Mechanics of Materials
File
Columns
P
y
A
L
B
x
$P_{cr} = \frac{\pi^2 EI}{L^2}$

ME 302 Course Outline Fall 2006

Course Outline, Fall 2006 Version 1.0, Effective 8/29/06

Dates	Ch	Sec	Topics	Homework Due Dates	Proposed Lab Plan
T 8/29 R 8/31	1 1	1-6 7-13	Concept of Stress, Normal Stress Components of Stress, Safety Factors	Send an e-mail to Dr. O'Toole so he can create a class list.	No Lab
T 9/5 R 9/7	2 2	1-8 9-10	Stress-Strain curves, Axial Loading Static Indeterminacy	Ch. 1: 6, 12, 17, 26, 36, 40, 47, 52	1: Safety & Statistics
T 9/12 R 9/14	2 3	11-15 1-4	Poisson's Ratio, Shearing Strain Torsion: Stresses, Angle of Twist	Ch. 2: 5, 13, 18, 27, 37, 44, 51, 66, 72, 81	2: Strain Gage Bonding
T 9/19 R 9/21	3 4	5-8 1-5	Statically Ind. Torsion, Power Bending: Stress & Deformation	Ch. 3: 2, 14, 28, 42, 50, 59, 68, 75, 82	2: Strain Gage Bonding
T9/26 R 9/28	 4	 6-12	**EXAM 1: Chapters 1-3** Bending: Eccentric Axial Loading	**Project Title**	3: Tensile Testing
T 10/3 R 10/5	5 5	1-2 3	Shear & Bending Moment Diagrams Load, Shear, & Moments	Ch.4: 7, 12, 18, 35, 46, 51, 103, 105	3: Tensile Testing
T 10/10 R 10/12	5 6	4 1-3	Design of Beams for Bending Shear Stresses in Beams		4: Torsion
T 10/17 R 10/19	6 6	4-6 7	Shear in Narrow Rectangular Beams Thin Walled Members	Ch. 5: 10, 20, 25, 27, 45, 46, 60, 68, 73	5: Beam Bending

Homework Policies

HOMEWORK ASSIGNMENT GUIDELINES:

Homework is due at the beginning of class on the dates highlighted in bold on the outline. For example, homework # 1 is due on Thursday, September 7. Homework assignments and due dates may change and will be announced in class. **Sloppy or unprofessional work will be returned ungraded. Late Homework Will Not Be Accepted** because solutions will be posted soon after the due date. Solutions will be posted on the MEG 302 Course Website. A password will be provided in class to allow access to the HW solutions.

Submit your assignments on 8.5" x 11" paper. Be sure to include your name at the top of the first page. Include the following information for each problem:

- Most of the problems will require a sketch of the problem along with one or more Free Body Diagrams showing the applied loads along with the external and internal reactions.
- Show all of your work. Make reference to equations in the book if you do not want to repeat them.
- Draw a box around your final answer or answers. You will not receive credit for a correct answer if you have not shown the work.

Each problem will be graded on a scale from 0-10. The homework counts as a significant percentage of your final grade so do not blow it off. Some of the problems may take several hours so manage your time accordingly. You are encouraged to help each other figure out the problems but do not copy each other's work.

The homework is assigned for three main reasons:

- To elaborate on material discussed in class and in the text
- To provide practice in solving mechanics problems
- To assess your understanding of the material

Office Hours and Grading

O'Toole Office Hours Fall 2006:

Monday: 10-2
Tuesday: 2-4
Wednesday: 10-2
Thursday: 1:30 – 2:30
Friday: 2-4

The best way to meet with me is to send e-mail to set up an appointment. I check my e-mail throughout the day and should respond quickly. I can be reached at:

Office Phone: **895 - 3885**
E-mail: **bj@me.unlv.edu**

GRADING

Your grade for the course will be based on weekly homework assignments, three in-class exams, a group design project and a comprehensive final exam which are weighted as shown below:

In-Class Exams (3)	Homework	Design Project	Final Exam
45 % (15 % each)	15 %	10 %	30 %

The letter grade cut-offs vary slightly from semester to semester. The table below shows an approximate correlation between final percentage grade and final letter grade.

88 - 100%	78 - 87%	73 - 77%	68 - 72%	58 - 67%	50 - 57%	< 50%
A	A- to B+	B	B- to C+	C	D	F

Additional Course Policies

CHEATING

Copying each other's homework assignments is considered cheating. Any form of cheating on homework or an exam will result in a failing grade for the course. All of the assigned homework problems have answers in the back of the book. Use this information to check your work. **DO NOT PUT THE ANSWER FROM THE BACK OF THE BOOK AT THE END OF YOUR PROBLEM IF YOUR WORK DOES NOT SUPPORT THIS ANSWER OR YOU WILL GET ZERO POINTS FOR THE ENTIRE ASSIGNMENT.**

Time Management

This will be a difficult class.
Plan to spend **6-10 hours per week** on homework assignments.
Plan to be completely stumped on some of the problems.
Plan your work periods at least **2 days before the due date.**
Plan to have questions after your first attempt at solving the homework problems.
Write your questions down when you think of them, **Ask** for help until you understand the problem.

DISABILITY RESOURCE CENTER

If you have a documented disability that may require assistance, you will need to contact the Disability Resource Center (DRC) for coordination in your academic accommodations. The DRC is located in the Reynolds Student Services Complex room 137. Their phone number is 895-0866.

Additional Resources

Engineers Edge
http://www.engineersedge.com/mechanics_material_menu.shtml

What is eFunda?

eFunda stands for engineering **Funda**mentals. Its mission is to create an online destination for the engineering community, where working professionals can quickly find concise and reliable information to meet the majority of their daily reference needs.

http://www.efunda.com/formulae/formula_index.cfm

Material Properties (MATWEB)
http://www.matweb.com/index.asp?ckck=1

Source of Materials
http://www.mcmaster.com/

Unit Conversion
http://www.digitaldutch.com/unitconverter/

Group Design Project

Scope of Project: The design project provides you with an opportunity to apply the topics learned in class to any mechanics oriented design problem of interest to you and your teammates. You and your team will be responsible for:

- Identifying a design problem (A list of examples is available on the course website)
  - (e.g. wall mounted bookshelf for home)
- Defining a specific set of objectives and constraints for the problem (ex. Below)
  - The bookshelf must support 20 textbooks and 20 large 3-ring binders
  - The bookshelf must not sag in the middle by more than 0.125 inches
  - The bookshelf must be less than 14 inches deep
- Use a standard design procedure for defining a list of design criteria, alternative designs to be considered, design variables, scheduling, analysis, etc. You should have completed a project like this as part of your Introduction to Engineering Design Course. An outline of this procedure is posted on the class website.
- You will not be building or testing anything for this project. Your project must specify a recommended design with specific dimensions, materials, and costs outlined. You must also make it clear how you arrived at this final design and show why it is better than other alternatives under consideration.

Selection of Project: You may choose any project provided it is:

- acceptable to the instructor
- utilizes (at least) the principles covered in Chapters 1 through 8
- Includes a group of 2-5 students
- You may not select a project that is a copy of a problem in the textbook.

Design Project Deadlines

Submit list of group members and project title: **September 28, 2006**

Send to bj@me.unlv.edu, include all student e-mail addresses along with the title of the project.

Final written report due by: **Friday December 8, 2006**

Report: The written report will be graded on its mathematical correctness, grammar, spelling, style of writing, clarity, and brevity, as well as other criteria usually applied to a written report. Send final report to bj@me.unlv.edu, as an attached MS WORD file. If you are not using MS WORD, see instructor. Hard copies of reports will NOT be accepted. All figures, drawings, equations, etc. must be imported into the report document. You can scan handwritten equations or use Equation Editor, MathType, MathCad, or a similar tool for equations.

Design Process (Part 1)

The following outline is a brief overview of the design process. You should be familiar with the design process from the required "Introduction to Engineering Design" course. The presentation and report for your project should include

- Identify Need
  - A customer usually approaches an engineer or engineering team with a problem. Your group must act as the customer initially by selecting a problem (approved by the instructor).
- Problem Definition
  - Try to come up with a specific definition of the problem
  - Consult with the customer before proceeding, make sure your definition matches the need
- Search for Information
  - Gather information from as many sources as possible
    - Library books
    - Library technical journals
    - Professional organizations
    - Internet (WWW)
  - Also examine existing products
- Criteria and Constraints (All projects will have different design criteria and constraints. The following is a partial list of possible criteria and constraints.)
  - Cost
  - Reliability
  - Weight
  - Ease of operation
  - Ease of Maintenance
  - Appearance
  - Strength
  - Compatibility
  - Safety Features
  - Noise Level
  - Effectiveness
  - Durability
  - Feasibility
  - Acceptance

Design Process (Part 2)

- Alternative Solutions (You must consider a minimum of 3 different solutions to your design problem.)
  - Initial brainstorming session should be very informal
  - Write down every idea mentioned
  - Everyone must feel comfortable stating their ideas
  - There will be many bad ideas that can be eliminated later
- Analysis (You must include some analysis covered in this class: axial loading, torsion, bending, combined loads, buckling, beam deflections, …)
  - Use your engineering knowledge to evaluate the alternatives based on your design criteria
- Decision Making
  - Use the results of your analysis to compare all the alternatives using a systematic process
- Specifications
  - Write a thorough description of your design
  - Include detailed drawings if needed
- Communication
  - Selling your idea
  - Written reports
  - Oral presentations
  - Visual aids

Design Project Ideas (Page 1)

Staircase Design	Airport Wind Guard	Bicycle Frame
Pull Trailer (for a car)	Retaining Wall	Diving Board
Closet Shelving System	Chair (Stool)	Guitar
3 Leg Table	RC Car Chassis	Small Porch
Book Shelf	RC Car Stand	Swing Set
Bike Rack	Computer Stand	Fishing Pole
Gazebo	Glasses	High Chair
Trebuchet	Automatic Adjustable Cane	Car Jack
TV Tray	Automatic Adjustable ladder	Stop Sign
Children's Playhouse	Automatic Adjustable Pencil	Freeway Sign
Foot Bridge	Adjustable Folding Table	TV Stand
Work Bench	Durable Bag for carrying Lathes	Aquarium Base
House Patio Cover	Artificial Limb	Engine Hoist

Design Project Ideas (Page 2)

Space Saving Hammock	Bus Stop Bench	Car Port
Residential Piping System	Portable Basketball Hoop	Automobile Seat
PVC Sprinkler System	Computer Chair	Computer Desk
Roll Cage for a Dune Buggy	Monkey Bars	Wheelchair
Compact Folding Stadium Seat	Lap Top Carrying Bag	Spring Board
Weight Lifting Bar	Pliers	Pandora's Safe
Rope Bridge	Neat Note Book	Indestructible Pita
Trampoline	Clutchless, intermittent fan	Water Couch
Slide	Mr. Flexy Snowboard	Steel Bridge
Traffic Signal	Spent Nuclear Fuel Rack	4x4 Tow Winch
Interstate Median	Auto Accident Reconstruction	

Good Luck This Semester !!