CVEN3525
Structural Analysis
Spring 2013

Jan. 13, 2016

LECTURES: T-Th 9:30-10:45 ECCR 105

INSTRUCTOR: Victor Saouma, saouma@colorado.edu
http://eae.colorado.edu/~saouma
Office: ECOT-450; Tel. 492-1622
Office hours: M-W 10:00-12:00; or anytime if available

TA/Grader Mohammed Zainy mohammed.zainy@colorado.edu
Office Hours: Monday : 1 :30-2 :45 ; Wednesday : 3 :30-4 :45 ; ECCE 1B52

TEXTBOOK: Hibbeler R.C., *Structural Analysis*, Prentice Hall, 9th ed.

WEB PAGE: This term we will be using Piazza for class discussion. The system is highly catered to getting you help fast and efficiently from classmates, the TA, and myself. Rather than emailing questions to the teaching staff, I encourage you to post your questions on Piazza. If you have any problems or feedback for the developers, email team@piazza.com

Find our class page at: https://piazza.com/colorado/spring2016/cven3525/home

PREREQUISITES: Passing grade (C-) in Mechanics of Materials
CVEN3525 is a prerequisite to CVEN-4545 (Steel Design), CVEN-4555 (Reinforced Concrete Design), CVEN-4525 Matrix Analysis

HOMEWORKS: Group work and submission are strongly encouraged. All homework are due on Thursdays at 9:30; late *homework are not accepted*.
Some homeworks will carry double weight.

EXAMINATIONS: Feb, 14; Mar. 14; May 6. There will be two quizzes and one final exam. At least one quiz/Final problem will be (nearly) identical to a homework one. Quizzes and final are closed book/notes.

TERM PROJECT: Optional, only for very motivated students with good standing, and at least a B+ in Mechanics and Matth courses

GRADING: Homework (30%), Quizzes (40%), Final (30%). The final grade will depend on the average of the two highest individual point totals (h) for the course. The final letter grade that you get is determined by taking your point total and putting it in one of these

Letter Grade	A	A-	B+	B	B-	C+	C	C-	F
Range of Point Total	h*1.00	h*.939	h*.919	h*.899	h*.819	h*.799	h*.779	h*.719	<h*.699
	h*.940	h*.920	h*.900	h*.820	h*.800	h*.780	h*.720	h*.700	

COMPUTERS: Some problems in this course may require the use of computers. In most cases, a general purpose spreadsheet program may suffice, however you are encouraged to use numerical analysis packages such as Matlab and MathCAD.

SOFTWARE: You have the choice for two structural analysis software:
1. Simple: MASTAN-2, Required as a minimum from all students

2. Advanced: RISA-2D, Required for those students who want to familiarize themselves with a well-known commercial code, and who may want to use it for a term project

Course Description

Structural analysis is necessary prior to any design. This introductory course will provide the technical foundation to properly understand the analysis of statically determinate (simple) and indeterminate (complex) structures such as cables, trusses, frames, arches. Whereas emphasis will be on 2D structures, you will also be exposed to some 3D cases. Techniques of analysis include flexibility (hand calculation) and stiffness (computer based) methods. You will also be exposed to a widely used commercial program for the analysis of structure, and will be encouraged to program in Matlab and use Mathcad for your assignments. There will be at least one presentation by a Structural Engineer who will discuss the challenges of the profession. Following is a *tentative* coverage.

Tentative Schedule; Jan. 14

Lecture	Week	Date			Coverage	Reading*	HW*		
							No.	Problems	Due
1	1	Jan.	T	12	Course description, syllabus, What is SE	1-1; 1-2	1	1-4; 1-18; 1-25	Th Jan 21
2			Th	14	Loads; Structural Design	1-3; 1-4			
3	2		T	19	Reactions	2-1 to 2-6	2*	2-16; 2-18; 2-20; 2-21; 2-27;	Th Jan 28
4			Th	21	Reactions				
5	3		T	26	Trusses, Method of Joints	3-1 to 3-3	3	3-12; 3-38	Th Feb. 4
6			Th	28	Trusses, Method of Section; 3D	3-5; 3-8			
7	4	Feb	T	2	Shear Moment Diagrams, Beam	4-1 to 4-3	4	4-14; 4-21; 4-48	T Feb 9
8			Th	4	Shear Moment Diagrams, Frame	4-4;			
9	5		T	9	Review for Test 1				
10			Th	11	**Test 1**				
11	6		T	16	Cable	5-1 to 5-3	5	5-3; 5-20	
12			Th	18	Arches	5-4; 5-5;			
13	7		T	23	Deflection: Elastic Curve;	8-1; 8-2;	6	8-5; 8-17; 8-23	
14			Th	25	Double Integration, Conjugate Beam	8-3;			
15	8	Mar	T	1	Principle of Virtual Work; Theory	9-1 to 9-3	7	9-1; 9-3; 9-13; 9-50	
16			Th	3	PVW; Trusses, Beams, Frames; Review	9-4; 9-7			
17	9		T	8	in Class problem Session				
18			Th	10	**Test 2**				
19	10		T	15	PVW Trusses; Force Method Introduction	10-1 to 10-4			
20			Th	17	Force Method; Beam, Trusses	10-5; 10-6;			
			T	22	**Spring Break**				
			Th	24					
21	11	Apr.	T	29	Force Method; Frames	10-8	8*	10-8; 10-9; 10-24; 10;40	
22			Th	31	Stiffness vs Flexibility; Slope Deflection	11-1; 11-2	9	11-8	
23	12		T	5	Slope Deflection	11-3			
24			Th	7	Moment Distribution; Beams	12-1; 12-2	10	12-5;	
25	13		T	12	Moment Distribution; Beams				
26			Th	14	Computer Based Analysis (SAP2000)	Handout	11	Sap2000 Assignment	
27	14		T	19	Matlab Review				
28			Th	21	Stiffness Method; Stiffness Matrix of beam and truss	Handout	12*	Matlab Assignment	
29	15		T	26	Stiffness Matrix of Frame Element; Orthogonal Structure				
30		May	Th	28	Stiffness Method; Orthogonal Structure				
			M	2	Final Exam 7:30-10:00 pm				
					HW* counts double				

ABET Course Objectives

The following ABET course objectives are met by this course**:**

- an ability to apply knowledge of mathematics, science, and engineering
- an ability to identify, formulate, and solve engineering problems
- an ability to communicate effectively through writing and drawings
- an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

PREREQUISITE KNOWLEDGE

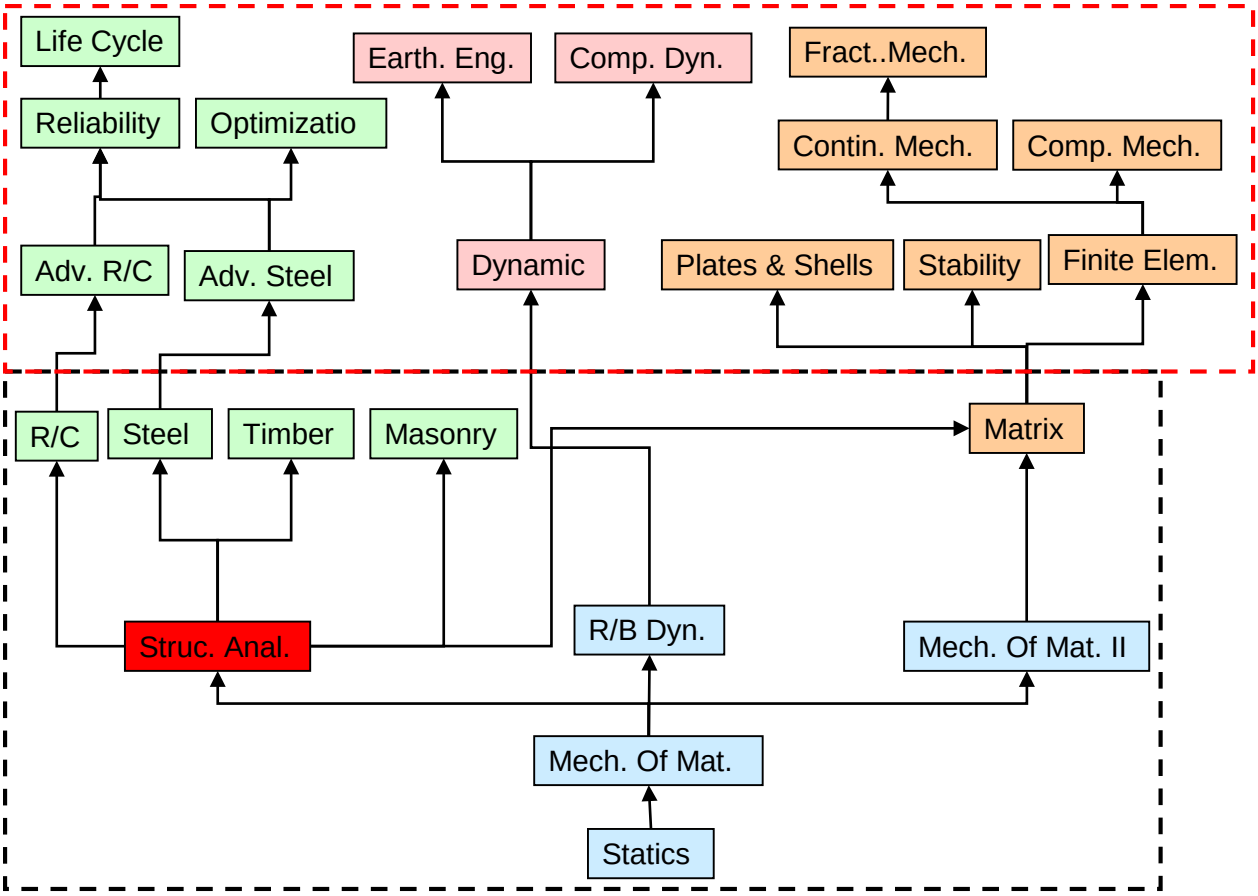
Static of Particles
Equilibrium of Rigid Bodies
Properties of Areas; 1st and 2nd Moments of area
Properties of Volumes - Center of Gravity
Analysis of Trusses
Internal Forces in Beams
Shear and Bending Moment Diagrams for Beams
Concept of Stress, Strain
Axial Loading of Rods
Torsion of Shafts
Pure Bending of Beams
Transverse Loading of Beams
Transformation of Stress and Strain
Elementary Design of Beams
Deflection of Beams by Integration Methods
Basic Matlab

HOMEWORK

Homework problems are designed to help you better understand and apply the material covered during the lectures. You are encouraged to discuss the problems and work together on the solutions. Homework consists of reading assignments and problem sets.

1. Teamwork is not only accepted but strongly encouraged, provided you list the percentage contribution of each student in order to properly adjust each grade. Not more than two students per group.
2. All work is to be presented on one side of 8 1/2 by 11 inch quadrille paper.
3. All sheets should contain a title consisting of your name, the date, the course title, and the problem being solved.
4. ~~Problems should be presented one problem per sheet or group of sheets with all sheets for each individual problem stapled together when handed in.~~
5. Each problem should include a complete statement of the problem being considered.
6. All figures should be drawn in a neat manner with a straight edge.
7. All dimensions important to the problem should be shown.
8. No more than 4 significant digits will be accepted.
9. Show all steps in the solution so that there is no question as to how any result was obtained. Do not present scratch work on the problem sheets.
10. Show all final results clearly with units inside a red box.
11. Each homework submitted with MATHCAD will automatically get a 5% bonus
12. Any homework not complying with the above rules, will not be graded (i.e 0). (Remember that the T.A. will try to minimize the time (s)he has to spend on grading).

Structural Mechanics/Engineering Course Sequence at CU-Boulder



E-MAILS:

University policy (http://www.colorado.edu/policies/email.html) states: *E-mail is an official means for communication within CU-Boulder. Therefore, the University has the right to send communications to students via e-mail and the right to expect that those communications will be received and read in a timely fashion.* Henceforth you will often be contacted by e-mail for: assignments, clarifications, quiz announcement and other course related matters. You will be contacted exclusively through your official CU issued e-mail address.
I will only respond to emails from a @colorado.edu (per ferpa guidelines)

Disabilities:

If you qualify for accommodations because of a disability, please submit to your professor a letter from Disability Services in a timely manner (for exam accommodations provide your letter at least one week prior to the exam) so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities. Contact Disability Services at 303-492-8671 or by e-mail at dsinfo@colorado.edu.

If you have a temporary medical condition or injury, see Temporary Injuries under Quick Links at Disability Services website (http://disabilityservices.colorado.edu/) and discuss your needs with your professor.

Following is a reply from the Disability services office from CU to an email enquiry.:

Thanks for contacting us. Typically, for students with 1.5 time and a DRE (Distraction reduced env.), the instructor is responsible for proctoring the exam. You can do this at the same time or at a different time than the regular exam time, in a space such as another classroom, or another space. You can contact your department to see what space would be available, and if you cannot find anything, contact Debbie.Otterstrom@colorado.edu. She is the campus scheduler.

For students with double time, a separate room accommodation, or other specific accommodations such as a reader or a scribe, or use of a computer to take exams, the student is allowed to take the exam in our office (we have very limited space). If this is the case, you and the student will fill out a proctoring form (the student is responsible for requesting one from us), and submit it to us no later than a week before the exam (longer for finals, we will announce these dates during the semester on our website). On rare occasions, we can proctor a student in our office who is just 1.5 time or DRE, but this is usually because of an extenuating circumstance where the instructor has no options to proctor.

Let me know if you would like any more clarifications. You can also feel free to call us at 303-492-8671.

Katie Weeman
Administrative Assistant
Disability Services
University of Colorado Boulder
Center for Community | Suite N200
Main: (303) 492-8671
www.colorado.edu/disabilityservices

Religion

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, {{insert your procedures here}}
See full details at http://www.colorado.edu/policies/fac_relig.html

Classroom Behavior

Students and faculty each have responsibility for maintaining an appropriate learning environment. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with differences of race, color, culture, religion, creed, politics, veteran's status, sexual orientation, gender, gender identity and gender expression, age, disability, and nationalities. Class rosters are provided to the instructor with the student's legal name. I will gladly honor your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the semester so that I may make appropriate changes to my records. See policies at
http://www.colorado.edu/policies/classbehavior.html and at
http://www.colorado.edu/studentaffairs/judicialaffairs/code.html#student_code

Discrimination

The University of Colorado Boulder (CU-Boulder) is committed to maintaining a positive learning, working, and living environment. The University of Colorado does not discriminate on the basis of race, color, national origin, sex, age, disability, creed, religion, sexual orientation, or veteran status in admission and access to, and treatment and employment in, its educational programs and activities. (Regent Law, Article 10, amended 11/8/2001). CU-Boulder will not tolerate acts of discrimination or harassment based upon Protected Classes or related retaliation against or by any employee or student. For purposes of this CU-Boulder policy, "Protected Classes" refers to race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, or veteran status. Individuals who believe they have been discriminated against should contact the Office of Discrimination and Harassment (ODH) at 303-492-2127 or the Office of Student Conduct (OSC) at 303-492-5550. Information about the ODH, the above referenced policies, and the campus resources available to assist individuals regarding discrimination or harassment can be obtained at http://hr.colorado.edu/dh/

Honor Code:

All students of the University of Colorado at Boulder are responsible for knowing and adhering to the academic integrity policy of this institution. Violations of this policy may include: cheating, plagiarism, aid of academic dishonesty, fabrication, lying, bribery, and threatening behavior. All incidents of academic misconduct shall be reported to the Honor Code Council (honor@colorado.edu; 303-735-2273). Students who are found to be in violation of the academic integrity policy will be subject to both academic sanctions from the faculty member and non-academic sanctions (including but not limited to

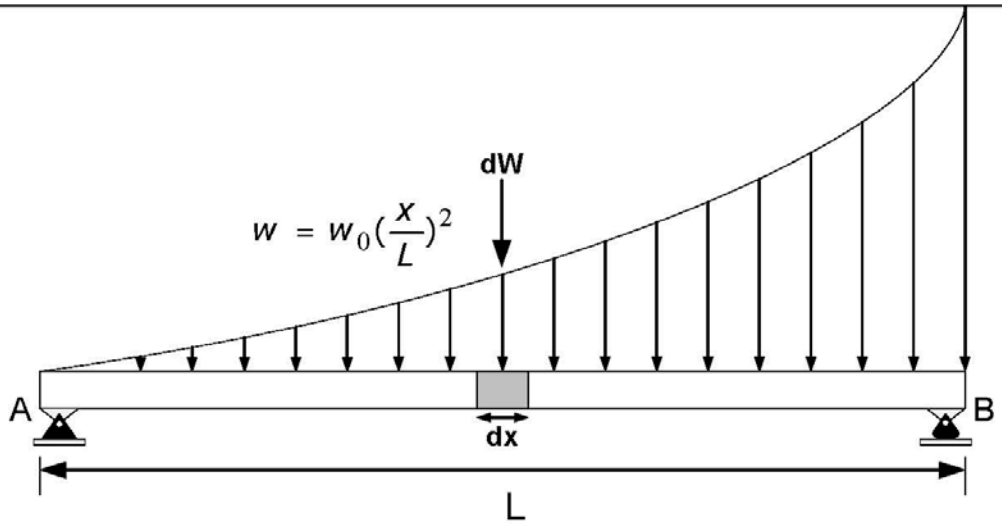
university probation, suspension, or expulsion). Other information on the Honor Code can be found at http://www.colorado.edu/policies/honor.html and at http://honorcode.colorado.edu

Mathcad Samples

Mathcad is a computer software that allows you to enter and manipulate text and mathematical equations, perform calculations, analyze and plot data, and format text.

It is extensively used by most companies for internal reports. You are strongly encouraged to adopt it for your homework submissions. There many tutorials you can download.

Following are samples of Mathcad solutions



Solution:

Since there are no axial forces, there are two unknowns and two equations of equilibrium. We have two equations of equilibrium ($\sum F_y$ and $\sum M$), we judiciously start with the second one, as it would directly give us the reaction at B. Considering an infinitesimal element of length dx, weight dW, an moment dM:

$$\sum M_z^A = 0 \qquad \int_{x=0}^{x=L} w_0 \cdot \left(\frac{x}{L}\right)^2 dx \times x - R_B \cdot L = 0$$

$$R_B = \frac{1}{L} \cdot w_0 \cdot \left(\frac{L^4}{4L^2}\right) = \frac{1}{4} \cdot w_0 \cdot L$$

With R_B determined, we solve for R_A from

$$\sum F_y = 0$$

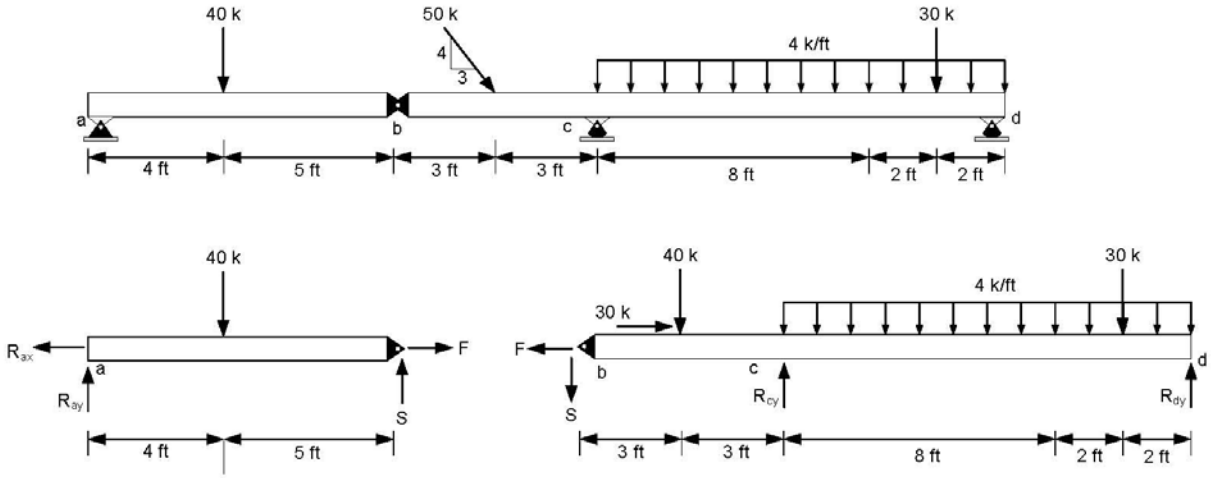
$$R_A + \frac{1}{4} \cdot w_0 \cdot L - \int_{x=0}^{x=L} w_0 \cdot \left(\frac{x}{L}\right)^2 dx = 0$$

$$R_A = \frac{w_0}{L^2} \cdot \frac{L^3}{3} - \frac{1}{4} \cdot w_0 \cdot L = \frac{1}{12} \cdot w_0 \cdot L$$

5.4 Three Span Beam

Determine the reactions of the following three span beam

Structural Analysis
Prof. Victor Saouma
Prepared by Christopher Segura



Solution:

We have 4 unknowns (R_{ax},R_{ay},R_{cy}, and R_{dy}), three equations of equilibrium and one equation of condition ($\sum M_b = 0$), thus the structure is statically determinate. Though there are many approaches to solve for those four unknowns (all of them correct), a few are simpler to pursue. In this case, it is easiest to "break" the structure into substructures and examine the free body diagram of each one of them separately.

1. Isolating ab:

$$\sum M_z^{\,b} = 0 \qquad 9\text{ft}\cdot R_{ay} - 40\text{kip}\cdot 5\text{ft} = 0 \qquad R_{ay} := \frac{40\text{kip}\cdot 5\text{ft}}{9\text{ft}} = 22.2\cdot\text{kip}$$

$$\sum M_z^{\,a} = 0 \qquad 40\text{kip}\cdot 4\text{ft} - S\cdot 9\text{ft} = 0 \qquad S := \frac{40\text{kip}\cdot 4\text{ft}}{9\text{ft}} = 17.8\cdot\text{kip}$$

$$\sum F_x = 0 \qquad R_{ax} := 30\text{kip}$$

2. Isolating bd:

$$\sum M_z^{\,d} = 0 \qquad -S\cdot 18\text{ft} - 40\text{kip}\cdot 15\text{ft} - 4\frac{\text{kip}}{\text{ft}}\cdot 12\text{ft}\cdot 6\text{ft} - 30\text{kip}\cdot 2\text{ft} + R_{cy}\cdot 12\text{ft} = 0$$

$$R_{cy} := \frac{S\cdot 18\text{ft} + 40\text{kip}\cdot 15\text{ft} + 4\frac{\text{kip}}{\text{ft}}\cdot 12\text{ft}\cdot 6\text{ft} + 30\text{kip}\cdot 2\text{ft}}{12\text{ft}} = 105.7\cdot\text{kip}$$

$$\sum M_z^{\,c} = 0 \qquad -S\cdot 6\text{ft} - 40\text{kip}\cdot 3\text{ft} + 4\frac{\text{kip}}{\text{ft}}\cdot 12\text{ft}\cdot 6\text{ft} + 30\text{kip}\cdot 10\text{ft} - R_{dy}\cdot 12\text{ft} = 0$$

$$R_{dy} := \frac{-S\cdot 6\text{ft} - 40\text{kip}\cdot 3\text{ft} + 4\frac{\text{kip}}{\text{ft}}\cdot 12\text{ft}\cdot 6\text{ft} + 30\text{kip}\cdot 10\text{ft}}{12\text{ft}} = 30.1\cdot\text{kip}$$