

University of Portland
School of Engineering

CE 401 - Computational Methods in Civil Engineering
(TR 11:20-12:45)
Fall Semester, 2007

Instructor: Dr. Matthew R. Kuhn (Room 103, 943-7361, kuhn@egr.up.edu)

Office Hours:

Texts and Resources:

Stephen J. Chapman, *Essentials of Matlab Programming*, Thomson Publ., 2006, ISBN 0-495-07300-8

Matthew R. Kuhn, *Computational Methods in Engineering*, 2005. Available at the University Print Shop, basement of Buckley Center.

Course Learning Objectives:

- To learn common computational analysis methods and use them in civil engineering applications.
- To learn how to apply these methods with computer spreadsheets and Matlab.
- To write Matlab programs. Matlab will serve as the primary higher-level programming language in the course.

Course Prerequisites: MTH321, Ordinary Differential Equations;
CE351, Structural Analysis I (co-requisite)

Assessment Tools:

Homework (14)	25 %
Quizzes (11)	15 %
Examination 1	17.5 %
Examination 2	17.5 %
Final examination	25 %

Evaluation: Grading will be based upon the School's definitions:

- “A” Denotes exceptional accomplishment
- “B” Denotes accomplishment significantly better than average
- “C” Denotes satisfactory accomplishment
- “D” Denotes accomplishment less than satisfactory but still passing.
- “F” Denotes failure (an average score less than 50%)

Course Objectives:

Learning objectives and outcomes	Assessment
<p>1. Learn common computational analysis methods and use them in civil engineering applications:</p> <ul style="list-style-type: none"> a) knows and can describe all words in the "Vocabulary" sections for booklet chapters b) able to recognize and explain items listed in the course syllabus c) can delineate the rules that underlie structured programming d) can compute the numerical derivatives of a data stream e) can recognize the "order of error" of an approximation f) can apply numerical integration techniques to a given function or data stream g) understands the relative errors of integration methods h) understands the basis of Gauss quadrature i) can perform matrix algebra operations on sample matrices j) understands and can symbolically apply matrix algebra properties k) can perform Gaussian elimination on sample matrices and understands the "elementary matrix" notation for Gaussian elimination l) understands the derivation of the LU factorization method and can perform the method on sample matrices m) understands three methods for computing a stiffness matrix and can apply them to sample structures n) understands and can compute a rotation matrix o) can estimate relative magnitudes of stiffness matrix elements p) can derive a member stiffness matrix q) can classify ordinary differential equations (ODEs) r) can use standard numerical methods methods for solving initial value problems s) can apply standard numerical methods to higher order ODEs and dynamic systems t) understands and can apply finite difference methods to solve boundary value problems u) can apply the finite difference method to an ODE boundary value problem v) can derive the differential equation for a beam 	<p>Homework Examinations</p>

1., cont.	Learn common computational analysis methods and use them in civil engineering applications, cont. w) can derive end and support conditions for a beam and give their finite difference form x) understands the finite difference matrix form of the beam problem y) can apply the finite difference method to elliptic problems in two dimensions	Homework Examinations
2.	Application of spreadsheet methods: a) can produce a spreadsheet to perform numerical differentiation and integration b) can produce spreadsheets to solve initial value problems of ordinary differential equations c) can use iteration to apply the finite difference method to boundary value problems in one dimension d) can use iteration to apply the finite difference method to flow problems in two dimensions	Homework Quizzes
3.	Writing Matlab programs: a) can use assignment statements b) can use the “if” and “for” control structures c) can write a Matlab function file for performing LU factorization with low-level assignment statements and control structures d) can perform matrix computations e) can use “for” loops for matrix computations f) can manipulate submatrices and perform matrix permutations g) can produce a program to perform truss analysis h) can apply the finite difference method with matrix operations, in one dimension	Homework Examinations Quizzes

Reading Assignments: You are expected to complete the reading assignments given in the syllabus *before* the class period. The text material will be covered on examination and on occasional quizzes at the beginning of class.

Homework:

- 1) Homework will be graded on the following criteria:
Method 50%
Correct results 30%
Neatness 20%
- 2) You may work with others on a homework assignment, but you must work *independently* on all Matlab assignments. No credit will be given for copied Matlab or spreadsheet programs.
- 3) Homework is due at the beginning of class.
Every homework assignment will count toward the final grade.
- 4) Include a cover page with each homework set.

Use either square grid engineering paper, blank (white) paper, or recycled paper.
Print on only one side of the paper.
Staple pages together.

- 5) Summarize the problem before giving the solution.
Present your solution in logically ordered and separate steps.
Be neat, points will be deducted for illegible writing.
- 6) Underline the final answer, *with its units*. You should give your answer with an appropriate number of significant figures that is consistent with the precision of the given data and your idealizations. This applies to spreadsheets as well.

Quizzes

Occasional quizzes are scheduled. Most quizzes will cover Matlab concepts, and they are scheduled on the days that major Matlab assignments are due.

Examinations

Exams will be closed book and closed notes, but with a formula sheet provided by the instructor. You should not expect the examination questions to be the same as those given in the homework assignments. Just as each homework question requires different solution methods and concepts (rather than repetitive drill), examination questions will likely be different than those in homework assignments.

There will be no make-up examinations and no credit for missed examinations. Cheating will result, at a minimum, in forfeiting an examination.

Academic Integrity

The University's Code and Guidelines of Academic Integrity are available on the web (www.up.edu > Academics > Registrar > Academic Regulations). Students should read and be familiar with the code and guidelines and should be aware of the various types of violations: cheating, forgery, and plagiarism. In this course, all violations will be considered as being of Level 2 or higher.

In particular, the University's Academic Integrity Policy considers the following behaviors as cheating: copying someone else's paper, and submitting the work of another as one's own. The university's policy on cheating and plagiarism includes homework assignments and to programming assignments. I encourage you to help each other on your homework and programs. Such help can include consultation about principles, concepts, and even syntax. Legitimate help can also include help with debugging homework and programs. Copying another student's paper, homework, or program is cheating and will be considered as being of Level 2 or higher. Penalties for first violations may include: 1) an academic warning for a stated period of time (not to exceed one year) during which time any further violation will constitute grounds for a Level 3 penalty; 2) assigning no credit to the work; 3) assigning a failing grade in the course; 4) writing a short paper on the ethical issues related to the violations and what was learned from the experience.

Accommodation for Disability:

If you have a disability and require an accommodation to fully participate in this class, contact the Office for Students with Disabilities (OSWD), located in the University Health

Center (503-943-7134), as soon as possible.

If you have an OSWD Accommodation Plan, you should make an appointment to meet with Dr. Kuhn to discuss your accommodations. Also, you should meet with Dr. Kuhn if you wish to discuss emergency medical information or special arrangements in case the building must be evacuated.

University of Portland
School of Engineering

CE 401 - Computational Methods in Civil Engineering
Homework Problems

Problem Set No. 1

1. Find a computer with Matlab (the Engineering computers, the Franz computers, or order your own student version of Matlab from www.mathworks.com for \$100). Read the first chapter in your Matlab text. While you are reading, perform all of the steps on the computer. Work independently.
2. Do exercise 1.1 on page 19 of your Matlab text. Work independently. Create the M-file "test1.m". Test the file by running it. Turn in a printed copy of test1.m.
3. Do exercise 1.4 on page 20. Work independently. You should turn in a hard copy of exercise 1.4. To create a hard copy of your session, create a "diary" file that echoes all of your keyboard input and screen output (see page 15 of your Matlab text). Before you do the exercise, you need to tell Matlab where to put your diary:

```
>>diary jessica.txt
```

or whatever you name is. This will begin the diary. When you are finished with the exercise, suspend the diary:

```
>>diary off
```

Then you can print your diary file (like "jessica.txt").
4. Matlab problem 2 on page 31. No need to use Matlab here unless you want to check your work. Work independently.
5. Matlab problems 3, 4, 5, and 6 on page 31. Replace 3(a) with the following:

```
u = [10 20 10+20];
```
6. Miscellaneous Matlab problems.

Problem Set No. 2

1. Problem 1 on page 39 of your Matlab text, parts (a), (b), (c), and (h) only. No need to use Matlab here unless you want to check your work.
2. Problem 2, page 39.
3. Problem 1, page 52, parts (a) through (e).
4. Problems 1 through 9, page 101.
5. Problem 1, page 116. Write an M-file with your code, and turn in a copy of the M-file. Work independently.
6. Miscellaneous Matlab problems.

Problem Set No. 3

1. Problem 3.11 on page 143 of your Matlab text. Write an M-file with your code, and turn in a copy of the M-file. Work independently.
2. Problem 4.1, page 191. Write an M-file with your code, and turn in a copy of the M-file. Work independently.

3. Problem 4.5, page 192. Write an M-file with your code, and turn in a copy of the M-file. Work independently.
4. Problems 4.7, (a) and (b). No need to use Matlab here unless you want to check your work.
5. Write an M-file to calculate the following sum. Use vectorization, not loops:

$$1^2 + 3^2 + 5^2 + \dots + 21^2$$

Problem Set No. 4

1. Problem 1.4 of your course booklet. Use Excel. Work independently on your spreadsheet.
2. Problem 1.10 of your course booklet.
3. Problem 1.12 of your course booklet.
4. Use Matlab and your own *.m script file to compute the first derivative of e^x at $x = 0$, as in the previous problem, using forward difference formulas of $O[\Delta x^2]$. Use step sizes of 0.1, 0.05, and 0.025. You may need to use the "format long" command. Compare the numerical results with the exact, mathematical value of the derivative, and discuss whether the effect of Δx on the accuracy is of $O[\Delta x^2]$. Work independently. Turn in a copy of your *.m file and your workspace that shows the results.
5. Miscellaneous Matlab problems.

Problem Set No. 5

1. Consider the following integral

$$\int_0^3 \left(\frac{3x}{1+x^2} \right) dx$$

Estimate the value of the integral using the trapezoidal rule, with $n = 4, 8,$ and 16 . Use an Excel spreadsheet.

2. The actual value of the integral in Problem 1 is 3.45388. Determine the order the error, $O[\Delta x^2]$.
3. Copy the email attachment "integ1.m" to your account to begin this problem. The program employs the rectangular rule to evaluate the integral $\int_0^1 \exp(x) dx$.
 - a) Modify the Matlab file to evaluate the integral in Problem 1, but using the trapezoidal rule.
 - b) Compute the integral for $n = 2, 4, 10, 100$. Based upon these results, determine the order of the error, $O[\Delta x^2]$.
4. Problem 2.5 of your text. Use 2 and 3 point formulas only.

Problem Set No. 6

1. Miscellaneous Matlab problems, assigned in class.
2. Use Matlab to perform the following matrix computations. Turn in Matlab output.
 - a) Multiplication of a matrix and a vector.

$$\begin{bmatrix} 2 & 1 & 1 \\ 4 & 1 & 0 \\ -2 & 2 & 1 \end{bmatrix} \begin{bmatrix} 3 \\ 1 \\ -1 \end{bmatrix}$$

b) Contraction (inner product) of two matrices,

$$\mathbf{A} = \begin{bmatrix} 2 & 1 & 1 \\ 4 & 1 & 0 \\ -2 & 2 & 1 \end{bmatrix}, \quad \mathbf{B} = \begin{bmatrix} -1 & 2 & 0 \\ 1 & 3 & 4 \\ 2 & -1 & -2 \end{bmatrix}, \quad \mathbf{A}:\mathbf{B} = \sum_{i,j} A_{ij}B_{ij}$$

c) Solving a matrix equation

$$\begin{bmatrix} 2 & 1 & 1 \\ 4 & 1 & 0 \\ -2 & 2 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 1 \\ -2 \\ 7 \end{bmatrix}$$

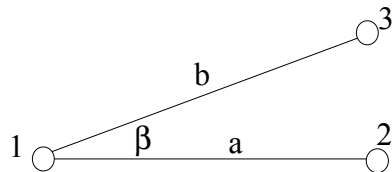
- Use Gaussian elimination to solve the matrix problem $[\mathbf{A}][\mathbf{x}]=[\mathbf{b}]$. You don't need to show the $[\mathbf{E}]$ matrices.
- Find the $[\mathbf{L}]$ and $[\mathbf{U}]$ matrices for the matrix in Problem 3. Solve the matrix equation $[\mathbf{A}][\mathbf{x}]=[\mathbf{b}]$ using the $[\mathbf{L}]$ and $[\mathbf{U}]$ matrices.

$$[\mathbf{A}] = \begin{bmatrix} 4 & 2 & 6 \\ 2 & 3 & 4 \\ 4 & 6 & 9 \end{bmatrix}, \quad [\mathbf{b}] = \begin{bmatrix} 0 \\ 3 \\ 7 \end{bmatrix}$$

- Use the Gaussian elimination program that we discussed in class to do LU factorization. I will mail an attachment gauss.m. You will write two *.m functions:
 - a function "LU.m" that produces the condensed matrix $[\mathbf{L}\backslash\mathbf{U}]$.
 - a separate function that uses the condensed $[\mathbf{L}\backslash\mathbf{U}]$ matrix to solve a system of linear equations.

Problem Set No. 7

- Use Method 1 to find the global stiffness matrix $[\mathbf{K}]$ of the structure shown below. Designate the stiffness of member i as $s_i (=A_i E_i / L_i)$.



- Exercise 8.8 in your Matlab text. Use a "while" loop. Turn in a copy of your *.m file.

Problem Set No. 8

- Use Method 2 to find the statics and member stiffness matrices, $[\mathbf{A}]$ and $[\mathbf{S}]$, of the structure shown above. The structure is 100 inches long and 50 inches tall. Both members have cross section areas of 1.50 in^2 . The modulus of elasticity is $10 \times 10^6 \text{ lb/in}^2$.
- Use the two Matlab files "truss_input.m" and "truss2d_m2.m" to find the stiffness matrix, $[\mathbf{K}]$, for the structure above.

Problem Set No. 9

1. Problem 3.9 of the course booklet.
2. Give the 6x6 transformation matrix [T] for Problem 1.
3. Problem 3.12 of the course booklet. Use Method 3.

Problem Set No. 10

Modify and complete the Matlab program "truss2d.m" to solve for the deflections and reaction forces in a two-dimensional frame.

Modify the input file "truss_input.m" to analyze the following frame structure. Note that it is statically indeterminate (and very much so). You should check the output results to see if the deflection pattern seems reasonable.

Turn in a copy of your program, your input file, and output.

Problem Set No. 11

1. Solve the following *nonlinear* ordinary differential equation for $x = 0$ to 1.5.

$$\frac{dy}{dx} = \sqrt{y + x^2}, \quad y(0) = 1$$

Use the midpoint method with a step size of 0.1. Use Excel. Don't just turn in your computer printout; develop the necessary equations on a separate sheet of paper.

2. Refer to example 4.1 in your text. Use Heun's method to find the motion (vs. t ?) for a pendulum with the following two initial conditions:

$$\text{At } t=0: \theta = \frac{\pi}{6} \quad \text{and} \quad \frac{d\theta}{dt} = 0 .$$

$$\text{At } t=0: \theta = 0.98\pi \quad \text{and} \quad \frac{d\theta}{dt} = 0 .$$

With rod length L is given as 0.2 m and g is 9.8 m/sec^2 , obtain the numerical solution over over a period of four oscillations (period = $1/f$). The frequency of the rod is given by

$$f \approx \sqrt{\frac{g}{4L \pi^2}} .$$

Write a Matlab script (*.m) file and use Heun's method. Use a step size no larger than $0.01/f$. Don't just turn in your computer printout. Develop the necessary equations on a separate sheet of paper. Plot the results for the two initial conditions as separate plots.

3. The roof of a building is laterally displaced 0.06 meters and then released. Determine the motion of the building at the roof level. Use a time step of less than $0.01 \sqrt{m/k}$ and determine the motion for a period of 1.5 seconds. Write a Matlab script (*.m) file and use the Euler method. Plot the roof level motions as a function of time. Don't just turn in your computer printout. Develop the necessary equations on a separate sheet of paper.

Problem Set No. 12

1. Solve the following boundary value problem using the finite difference method:

$$y'' + x y' - xy = 2x, \quad y(0) = 1, \quad y(1) = 0$$

Break the interval $[0,1]$ into five subintervals ($n = 5$). Show the general relationship between y_i , y_{i-1} , and y_{i+1} , and give the final simultaneous equations in matrix form. Solve with Matlab. Plot the results using Matlab.

2. Solve the following boundary value problem using the finite difference method. Find the general relationship among T_i , T_{i-1} , and T_{i+1} . Solve for the range $r=(0,1)$ with 10 subintervals. Use central difference formulas to approximate the O.D.E., but use a forward difference estimate of the derivative at $r=0$. Use Excel and iteration. Plot T vs. r .

$$\frac{d^2 T}{dr^2} + \frac{1}{r} \frac{dT}{dr} + 1 = 0, \quad T(r=1) = 1, \quad \frac{dT}{dr}(r=0) = 0$$

Problem Set No. 13

1. Derive the finite difference equation for beam flexure at the spring support.
2. Create a Matlab script file (*.m file) to analyze the beam. You may want to look at the two email files beam1.m and beam2.m.

Turn in a copy of your program and output.

Problem Set No. 14

1. Solve for the temperatures of the heated plate. After deriving the finite difference equations, solve using Excel with iteration.

University of Portland
School of Engineering
CE 401 - Computational Methods in Civil Engineering
Syllabus
Fall Semester, 2007

Lesson No.	Date	Topics	Matlab text (Course booklet)	Number (Due) pts
1	8-28	Course introduction Matlab programming concepts	Matlab, Chap. 1 & pp. 21-31	No. 1 (2) 10pts
2	8-30*	Programming concepts, cont.	Matlab pp. 35-42, 46-52, & 85-112	No. 2 (3) 10 pts
3	9-4*	Programming concepts, cont.	Matlab, pp. 147-163	No. 3 (4) 10 pts
4	9-6*	Programming concepts, cont. Numerical Differentiation	Matlab, pp. 199-223 (1.1-1.3)	No. 4 (6) 15pts
5	9-11	Numerical differentiation, cont.	(1.4-1.6)	
6	9-13*	Numerical Integration Newton-Cotes formulas Gauss quadrature	(2.1-2.3)	No. 5 (8) 15pts
7	9-18	Gauss quadrature, cont. Linear Algebraic Equations Matrix review	(2.5) Matlab, 10.1-2 (except inlines)	
8	9-20*	Gaussian elimination Partial pivoting		No. 6 (11) 10pts
9	9-25	LU factorization		
10	9-27	LU factorization, cont. Matlab programming of LU methods		
11	10-2*	Analysis of Two-Dimensional Truss Structures Problem definition Direct solution method	(3.1-3.3)	No. 7 (12) 10pts
12	10-4	Statics and kinematics matrices	(3.5)	No. 8 (15) 10pts
13	10-9	Examination No. 1 Member stiffness matrix		
14	10-11	Member stiffness matrix, cont. Reference frame transformations Transformed member stiffness matrix	Matlab, Chap. 8 (except menus) (3.7)	No. 9 (17) 15pts
15	10-23*	Stiffness matrix assembly Structural support conditions	(3.8)	
16	10-25	Stiffness matrix partitioning Computer application, stiffness method	(3.10)	No. 10 (19) 15pts

17	10-30*	Computer application, stiffness method, cont.		
18	11-1	Computer application, stiffness method, cont.	(4.1-4.3)	
		Ordinary Diff. Eqns. (init. value problems)		
		Review of concepts		
19	11-6*	Euler's method Improvements on Euler's method		No. 11 (21) 15pts
20	11-8	Higher order equations Multi-body dynamic systems	(4.4)	
21	11-13*	Boundary Value Problems Introductory concepts Finite difference method	(5.6-5.7)	No. 12 (23) 10pts
22	11-15	Finite difference method, cont. Elastic beam analysis Equilibrium and constitutive relations Finite difference form Elastic beam analysis, boundary conditions	(5.8)	No. 13 (25) 10pts
23	11-20	Computer analysis of beams	(5.9)	
24	11-27	Examination No. 2 Computer analysis of beams, cont.		
25	11-29*	Partial Differential Equations Introductory concepts Classification of equations and civil engineering examples Elliptic problems, Finite difference method		No. 14 (26) 10pts
26	12-4	Finite difference methods, cont.		
27	12-6	Finite difference methods, cont. Course summary		
	Dec. 12 (Wed.)	1:30-3:30 <i>Final Examination</i>		

* Quizzes