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Course Outline for ENGR 25

COMPUTATIONAL METHODS FOR ENGINEERS AND SCIENTISTS

Effective: Spring 2010

I. CATALOG DESCRIPTION:
ENGR 25 — COMPUTATIONAL METHODS FOR ENGINEERS AND SCIENTISTS — 3.00 units

Methodology and techniques for solving engineering/science problems using numerical-analysis computer-application programs MATLAB and EXCEL. Technical computing and visualization using MATLAB software. Examples and applications from applied-mathematics, physical-mechanics, electrical circuits, biology, thermal systems, fluid systems, and other branches of science and engineering. Prerequisite: Mathematics 1 (completed with a grade of "C" or higher). Strongly recommended: Computer Science 7.

2.00 Units Lecture 1.00 Units Lab

Grading Methods:
Letter Grade

Discipline:

	MIN
Lecture Hours:	36.00
Lab Hours:	54.00
Total Hours:	90.00

II. NUMBER OF TIMES COURSE MAY BE TAKEN FOR CREDIT:

III. PREREQUISITE AND/OR ADVISORY SKILLS:

IV. MEASURABLE OBJECTIVES:

Upon completion of this course, the student should be able to:

A. analyze engineering/science word problems to formulate a mathematical model of the problem
B. express in MATLAB notation: scalars, vectors, matrices
C. perform, using MATLAB or EXCEL, mathematical operations on vectors, scalars, and matrices
    1. addition and subtraction
    2. multiplication and addition
    3. exponentiation
D. compute, using MATLAB or EXCEL, the numerical-value of standard mathematical functions
    1. trigonometric functions
    2. exponential functions
    3. square-roots and absolute values
E. import data to MATLAB for subsequent analysis from data-sources
    1. data-acquisition-system data-files
    2. spreadsheet files
F. construct graphical plots for mathematical-functions in two or three dimensions
G. formulate a fit to given data in terms of a mathematical curve, or model, based on linear, polynomial, power, or exponential functions
    1. assess the goodness-of-fit for the mathematical model using regression analysis
H. apply MATLAB to find the numerical solution to systems of linear equations
    1. uniquely determined
    2. underdetermined
    3. overdetermined
I. perform using MATLAB or EXCEL statistical analysis of experimental data to determine the mean, median, standard deviation, and other measures that characterize the nature of the data
J. compute, for empirical or functional data, numerical definite-integrals and discrete-point derivatives
K. solve numerically, using MATLAB, linear, second order, constant-coefficient, nonhomogenous ordinary differential equations
L. assess, symbolically, using MATLAB
    1. the solution to transcendental equations
    2. derivatives, antiderivatives, and integrals
    3. solutions to ordinary differential equations
M. apply, using EXCEL, linear regression analysis to xy data-sets to determine for the best-fit line the: slope, intercept, and correlation-coefficient
N. draw using MATLAB or EXCEL two-dimensional Cartesian (xy) line-plots with multiple data-sets (multiple lines)
O. draw using EXCEL qualitative-comparison charts such as Bar-Charts and Column-Charts in two or three dimensions
P. perform, using MATLAB and EXCEL, mathematical-logic operations

V. CONTENT:

A. Engineering problem solving
   1. Construct Physical Model
   2. Construct Mathematical Model
   3. Solve using graphic-geometrical, analytical, or numerical methods

B. Using MATLAB
   1. User interface and working-environment
   2. Writing MATLAB software-code using script or function files (".m" files)
   3. MATLAB Mathematical functions, including logical operations
   4. Graphical output

C. MATLAB linear algebra using arrays and matrices
   1. Array and Matrix mathematical operations: addition/subtraction, multiplication/division exponentiation, transpose

D. MATLAB Files and Data Structures
   1. Importing data from ASCII and spreadsheet files
   2. Complex number formats, rectangular and polar

E. Programming with MATLAB
   1. Psuedocoding (written-english description of the intended program-function)
   2. Basic flow charting
   3. State transition diagrams
   4. Conditional Branching using if/then/else techniques
   5. Conditional Loops
   6. DeBugging MATLAB programs using the Editor/Debugger

F. MATLAB graphical-output and curve-fitting
   1. Two dimensional Cartesian (XY) plots using multiple data-sets with proper scaling and labeling
      a. Linear-linear
      b. Log-linear (semilog)
      c. Log-log
   2. Data-set curve fitting with regression analysis
      a. Linear
      b. Polynomial/power function
      c. Exponential function
   3. Three dimensional plots: line, surface mesh, contour

G. Solutions to systems of linear equations
   1. Gaussian elimination
   2. Matrix inversion decomposition
   3. Cramer's method
   4. Underdetermined systems and the minimum-norm solution
   5. Overdetermined systems and the least-squares solution

H. MATLAB and EXCEL statistical analysis for empirical data
   1. Calculate standard statistical metrics: mean, median, mode, standard deviation, minimum, maximum, range
   2. Generate random numbers
   3. Linear interpolation

I. MATLAB numerical integration and differentiation
   1. Trapezoidal integration
   2. Simpson's rule integration
   3. Numerical differentiation
      a. Forward difference
      b. Backward difference
      c. Central difference

J. MATLAB solutions for ordinary differential equations
   1. Runge-Kutta based ODE solvers
      a. Stiff and nonstiff systems
      b. Low, medium, and variable order solvers

K. MATLAB symbolic mathematics
   1. Mathematical-expressions and algebra
   2. Solve algebraic and transcendental equations
   3. Ordinary and partial differentiation
   4. Antiderivatives and definite integrals
   5. Solve linear and nonlinear ordinary differential equations

L. EXCEL user-interface and working-environment

M. EXCEL mathematical functions including logical operations

N. EXCEL graphical output
   1. Bar and column charts
   2. Line and xy plots
   3. Three dimensional surface plots

O. EXCEL statistical analysis, and curve fitting including linear regression

VI. METHODS OF INSTRUCTION:

A. **Lecture** - Formal lectures using PowerPoint and/or WhiteBoard presentations
B. **Demonstration** - Computer demonstrations
C. **Discussion** - Class discussion of problems, solutions and student's questions
D. **Lab** - Laboratory use of computers
E. Reading from the text

VII. TYPICAL ASSIGNMENTS:

A. Read chapter-2 in the text on MATLAB's Array and Matrix handling functions B. Exercises from the text book, or those created by the instructor 1. A set of three equations defines the mesh currents in shown in Text Figure 5.5. Write at MATLAB program to compute the mesh currents using the given resistor and voltage-source values 2. The Useful life of a machine bearing depends on its operating temperature as indicated by the following data: Temperature (°F) 100 120 140 160 180 200 220 Bearing Life (kHr) 28 21 15 11 8 6 4 Obtain a functional description (curve fit) for this data. Plot the function and the data on the SAME plot. Also estimate bearing life for a 150 °F operating temperature. 3. Given that i = , let y = -3 + ix. For x = 0, 1, 2 use MATLAB to numerically evaluate the following expressions. Hand check your answers. a. |y| b. c. (-5-7i)y d. y/(6-3i) 4. Consider an Ordinary Differential Equation (ODE) and its analytical solution: Ordinary Differential Equation Solution Verify the solution using two methods a. By hand take the analytical derivative of x(t) and substitute in to the ODE. b. Solve the ODE symbolically using MATLAB's dsolve function 5. Given a set of deflection vs. load data for a cantilever beam use EXCEL to plot the data and calculate the slope of the best straight line through the data. 6. A DIODE is an electronic component that essentially acts as "check valve" for electrical current; i.e., the diode allows current flow in one

direction, but not the other. The electrical circuit symbol, and the theoretical equation relating the diode current to the electrical potential (or pressure) in applied across the diode: Circuit Symbol V-I Relation Where • Va ? the Applied Electrical Potential in Volts (V) • I ? the Diode Current in Amps • Isat ? the Diode SATURATION Current, a PRACTICAL constant, in Amps • q ? the ELECTRONIC CHARGE, a UNIVERSAL constant = 1.6 x10-19 Coulombs • k ? BOLTZMANN'S value, a UNIVERSAL constant = 1.3805 x10-23 J/K • n ? the Diode IDEALITY FACTOR, a PRACTICAL constant without units • T ? the Thermodynamic Temperature in Kelvins (K) An instrument called a Digital MultiMeter, or DMM (which we will use in ENGR44) can be used to collect Va vs. I data. The CSV (Comma Separated Values) data file provided by the instructor contains Va ? 0 data for a 1N4123 silicon diode. • Use these data to create a SOME TYPE of Plot to reveal the values of the practical constants: o Isat o n • Based on your analysis, comment on the quality/reliability of the values for Isat and n 7. The height, H, reached by a bubble rising through a liquid in time ?r may be calculated using the double integral equation . Find the rise velocity, vr, from Using the instructor-provided values for the constants ro, CD, and g, determine for the specified rise time the value of H.

VIII. EVALUATION:

A. **Methods**

1. Exams/Tests
2. Lab Activities
3. Other:
    a. Exams
    b. Programs
    c. Lab Work

B. **Frequency**

1. Exams
    a. 1 midterm exam during semester
    b. 1 final exam
2. Programs
    a. Every week

IX. TYPICAL TEXTS:

1. A. Dolores Etter, David Kuncicky, Holly Moore *Introduction to MATLAB 7.*, Prentice Hall, 2005.
2. William Palm *Introduction To MATLAB 7 For Engineers.*, McGraw-Hill, 2005.
3. Amos Gilat *MATLAB, an Introduction with Applications.* 3rd ed., John Wiley, 2008.
4. Bernard Liengme, Butterworth-Heinemann *Guide to Microsoft Excel 2007 for Scientists and Engineers.* 4th ed., Elsevier Science, 2008.
5. Byron S. Gottfried *Spreadsheet Tools For Engineers Using Excel 2007.*, McGraw-Hill, 2009.
6. S. C. Bloch *EXCEL for Engineers and Scientists.* 2nd ed., John Wiley, 2003.

X. OTHER MATERIALS REQUIRED OF STUDENTS:

A. Some form of file storage, e.g., USB drive or similar