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Course Outline for ENGR 25

COMPUTATIONAL METHODS FOR ENGINEERS AND SCIENTISTS

Effective: Spring 2019

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.

2.00 Units Lecture 1.00 Units Lab

Prerequisite
MATH 1 - Calculus I
with a minimum grade of C

Strongly Recommended
CS 7 - Introduction to Computer Programming Concepts
with a minimum grade of C

Grading Methods:
Letter Grade

Discipline:
- Engineering

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

II. NUMBER OF TIMES COURSE MAY BE TAKEN FOR CREDIT: 1

III. PREREQUISITE AND/OR ADVISORY SKILLS:

Before entering the course a student should be able to:

A. MATH1
1. Determine whether a function is continuous at a point or an interval;
2. Interpret the derivative as the slope of a tangent line and find the equation of a tangent line to a function;
3. Explain the definitions of velocity and acceleration and use the derivative to find the velocity and acceleration of an object in motion, given the position function for the object;
4. State and apply the rules for differentiating algebraic and trigonometric functions.
5. Utilize the chain rule when differentiating functions;
6. Use calculus-based methods to analyze functional behavior;
7. Utilize Newton's Method;
8. Apply the Fundamental Theorem of Integral Calculus;

Before entering this course, it is strongly recommended that the student should be able to:

A. CS7
1. Design simple algorithms to solve a variety programming problems.
2. Design and implement programs of short to medium length, using standard elements of programming languages such as variables, input/output, control structures, functions/methods and arrays.
3. Explain what an algorithm is and its importance in computer programming.
4. Analyze and investigate program behavior to effectively alter or debug existing code.
5. Design and implement specific program steps and components to achieve desired program behavior.
6. Design and organize elements of a program using a structured representation such as pseudocode and/or flowcharts.
7. Design and implement simple graphical and command line user interfaces implementing the students algorithms.

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. Use MATLAB or EXCEL environment to define variables, and perform mathematical operations on vectors, scalars, and matrices
C. Write programming instructions in script files and run the script files
D. Import data to MATLAB for subsequent analysis from data sources
E. Construct graphical plots for mathematical functions in two or three dimensions
F. Formulate a fit to given data in terms of a mathematical curve, or model, based on linear, polynomial, power, or exponential functions, and assess the goodness-of-fit for the mathematical model using regression analysis
G. Apply MATLAB to find the numerical solution to systems of linear equations
H. 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
I. Compute, for empirical or functional data, numerical definite integrals and discrete-point derivatives
J. Solve numerically, using MATLAB, linear, second order, constant-coefficient, nonhomogenous ordinary differential equations
K. Assess the solution to transcendental equations, derivatives, integrals, and solutions to ordinary differential equations symbolically using MATLAB
L. Apply, using EXCEL, linear regression analysis to xy data-sets to determine for the best-fit line the: slope, intercept, and correlation-coefficient
M. Draw using MATLAB or EXCEL two-dimensional Cartesian (xy) line-plots with multiple data-sets (multiple lines)
N. Draw using EXCEL qualitative-comparison charts such as Bar-Charts and Column-Charts in two or three dimensions
O. Perform, using MATLAB and EXCEL, mathematical-logic operations

V. CONTENT:

A. Introduction to computer programming and engineering problem solving
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
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. Problem solving methodologies, psuedocoding, and basic flow
    2. Conditional Branching using if/then/else techniques, and conditional loops
F. MATLAB graphical-output and curve-fitting
    1. Two dimensional Cartesian (XY) plots using multiple data-sets with proper scaling and labeling
    2. Data-set curve fitting with regression analysis
    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 data set
    1. Calculate standard statistical metrics: mean, median, mode, standard deviation, minimum, maximum, range
    2. Generate random numbers
    3. Linear interpolation
    4. Curve fitting including linear regression
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

VI. METHODS OF INSTRUCTION:

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

VII. TYPICAL ASSIGNMENTS:

A. Read the section in Chapter 9 on nested loops in order to write a program to determine the maximum value of the matrix with n rows and m columns.
B. Study numerical integrations and write a program to calculate the area under a curve.
C. Program a MATLAB algorithm to fit a quadratic function to the experimental data.
D. Plot a given function within a desired data range using MATLAB and EXCEL.
E. 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. (a) Obtain a functional description (curve fit) for this data. Plot the function and the data on the SAME plot. (b) Also estimate bearing life for a 150 °F operating temperature.

F. Consider an Ordinary Differential Equation (ODE) and its analytical 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.
G. 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.

VIII. EVALUATION:
Methods/Frequency

A. Exams/Tests
two midterms and one final exam
B. Quizzes
three to five
C. Lab Activities
weekly

IX. TYPICAL TEXTS:

1. Moore, Holly. *MATLAB for Engineers.* 5th ed., Pearson, 2018.
2. Etter, Delores. *Introduction to MATLAB.* 3rd ed., Pearson, 2015.
3. Liengme, Bernard . *Guide to Microsoft Excel 2007 for Scientists and Engineers.*. 4th ed., Elsevier Science, 2008.
4. Palm, William. *Introduction to MATLAB for Engineers.* 3rd ed., McGraw Hill, 1994.
5. Hahn, Brian, and Daniel Valentin. *Essential MATLAB for Engineers and Scientists.* Sixth ed., Elsevier, 2017.

X. OTHER MATERIALS REQUIRED OF STUDENTS:
A. Some form of file storage, e.g., USB drive or similar