ENGINEERING TOOLS – ENGR 110 **LAB 3**
PURPOSE: More Excel – Curve fitting and solving equations. MatLAB programming

DESCRIPTION: Do all problems.

EXCEL WORK

A. CURVE FITTING – Engineers frequently collect paired data (x,y) in order to understand the characteristics of an object or behavior of a system (temp vs. distance or voltage vs. time for example). Representing this data with a mathematical function (like a straight line or an exponential function) is a powerful analytical tool.

Problems 1 and 2 have you using curve fitting. Problem 1 has you using the linear regression math equations to fit the curve to the data. Problem 2 uses Excel's built in function to do the same thing(which you will find is MUCH quicker than what you do in problem 1!).

1. Fitting a STRAIGHT LINE: Let's assume we've collected the following velocity and time data:

Time	Velocity
0.1	211.25
0.12	227.75
0.13	243.5
0.15	259.55
0.17	275.5
0.18	291.5
0.2	308
0.22	324.25
0.23	340.3
0.25	356
0.27	372.7
0.28	388.75

Now we want to find the best straight line through this data and measure its goodness of fit. To do that, we need to find the slope (named M), the Y intercept (named B), and the correlation coefficient (named r).

We will calculate these values using our spreadsheet (INSTEAD OF USING EXCEL'S BUILT IN FUNCTION) to practice using Excel and typing in formulas. We can use Excel's built in function to check our answers.

FOLLOW THESE INSTRUCTIONS:

a. Enter the data into the spreadsheet
b. Plot this data on a xy scatter chart. Does it look like it could be a straight line? It should.

c. Calculate the slope of the line that best fits this data using the following formula. All calculations should be done in Excel.

Slope= <u>(number of paired data)*(sum of each X*Y)-(sum of X's)*(sum of Y's)</u>
(number of paired data)*(square each X then sum)-(sum of X's)*(sum of X's)

The number of paired data is just how many XY ordered pairs you have. In this example, **the number of paired data is 12.**

Helpful Hint: Instead of trying to type this in as one very, very long formula, break it up in to smaller parts. For example, create another column in your spreadsheet to calculate each X*Y, then sum that column. Next, sum the X (time) column, then sum the Y column. Now, anywhere in the spreadsheet, calculate the numerator. Now do the same thing for the denominator. When you have both the numerator and denominator calculated, all you have to do is divide them to get the slope.

This method makes it MUCH easier to fix your spreadsheet if you have a math error.

This method is helpful for calculating the y-intercept and correlation coefficient too.

d. Calculate the y-intercept using the following formula. All calculations should be done in Excel

Y int = <u>(square each X then sum)*(sum of Y's)-(sum of X's)*(sum of each X*Y)</u>
(number of paired data)*(square each X then sum)-(sum of X's)*(sum of X's)

e. We now have the equation of the line, y=mx + b. **Use this equation, with your values for m and b and the original values for x to calculate new values for y.** Are these new y values close to the original y values? They should be if this line is a good fit!

f. Calculate the correlation coefficient, which measures goodness of fit. Use this formula: NOTE: **N=number of paired data = 12 here**

$$\frac{(\boldsymbol{N * sum\ of\ each\ X * Y}) - (\boldsymbol{sum\ X's * sum\ Y's})}{\sqrt{(\boldsymbol{N * square\ each\ X\ then\ sum - sumX's * sumX's}) * (\boldsymbol{N * square\ each\ Y\ and\ sum - sumY's * sumY's})}}$$

The correlation coefficient will always be less than or equal to 1.0. The closer to 1.0, the better the fit (1.0 is a perfect fit). **This should show that it is a good fit.**

2. Fitting an EXPONENTIAL FUNCTION: The transient behavior of a capacitor has been studied by measuring the voltage drop across the device as a function of time. We've collected the following data (NOTE the last time value is correct at 12 – it's not supposed to be 11):

TIME	VOLTAGE	TIME	VOLTAGE	TIME	VOLTAGE
0	10	4	1.4	8	.2
1	6.1	5	.8	9	.1
2	3.7	6	.5	10	.07
3	2.2	7	.3	12	.03

There is a method to fit an exponential curve to this data similar to what we did above for the straight line. This time, rather than typing in all the formulas, we'll use the built in Excel function. Follow these instructions:

a. Enter the data into an Excel spreadsheet – time in the first column, voltage in the second column.

b. Plot the data as an xy scatter plot (do not connect the points)

c. While clicked on the graph, click on the CHART TOOLS tab, click the LAYOUT tab. Now click TRENDLINE and then click MORE TRENDLINE OPTIONS. Click on EXPONENTIAL type.

d. Click on EXPONENTIAL type and also click on the DISPLAY EQUATION ON CHART and DISPLAY R-SQUARED VALUE ON CHART boxes right at the bottom of this menu.

e. Click CLOSE. You should now have a chart showing the trend line, exponential equation, and r value. Is the exponential function a good fit for this data? How do you know?

B. SOLVING EQUATIONS – (see week 3 notes for info on this). Engineers are often required to solve complicated algebraic equations. Excel provides several features to assist with this task. We will use Goal Seek to help us solve a single equation. (NOTE: Excel also has the capability to solve simultaneous equations using matrix operations – we don't use this).

The following information is known about solving polynomial equations:

- An nth degree polynomial can have no more than n real roots (X values where Y=0).
- If the degree of a polynomial is odd, there will always be at least one real root

3. Consider the equation: $2X^5 - 3X^2 - 5 = 0$. This equation has at most 5 real roots and at least one real root. Solving equations means we're looking for the roots – Roots are the X values that make the equation true (ie. Make Y=0). The first thing we always want to do is graph the equation to get picture of where the root(s) might be. Then we will use Goal Seeker to determine the root(s).

Follow these instructions (again, see notes on Blackboard for more details):

a. Make a chart in Excel that lists X, Y ordered pairs for the equation above. To do this, pick a range of X values, then use excel and the given equation to calculate the corresponding y values. Use X values here: -5,-4,-3,-2……..4,5.

b. Plot this data using an XY scatter plot. Can you estimate a root of this equation from the graph? Remember, the root will be where the function crosses the x axis because that is where Y=0.

c. In a cell in your spreadsheet, enter an initial guess for the root of the equation.

d. In another cell, enter the equation. Use the cell location of your initial guess as the variable in the equation.

e. Click on the DATA tab and then select WHAT IF ANALYSIS. Then click on GOAL SEEK. In the dialog box, enter the cell location of the formula in the SET CELL area. Enter zero in the TO VALUE area. Enter the cell address of the initial guess in the BY CHANGING area. Now select OK.

At this point, if Excel could find a solution, it will be in the initial guess cell. Excel should have found a root for this equation.

Use this procedure to solve the following:
4. Determine a real root for $3X^3 + 10 = 0$
5. Determine the two real roots between x= -5 and x=5 for X + COSX=1+SINX. Note: To find more than one root, you must do goal seek more than one time, each time with a different guess.

6. In order to determine the temperature distribution within a one-dimensional solid, engineers must often solve the equation: XtanX=c, where c is a known positive constant. Assuming a value of c=2, find the three smallest positive roots of XtanX=2.

MATLAB WORK

Write your own script file in MATLAB for the following problem:

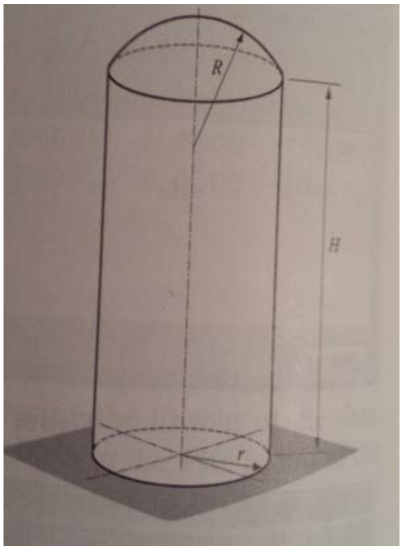
A cylindrical silo with radius r has a spherical cap roof with radius R. The height of the cylindrical portion is H. The height of the cap is h. (See sketch below)

Write a program that determines the cylindrical height H for given values of r, R and the total volume of the silo V.

You will find the following equations useful:
Vcap=Volume of cap=(1/3)pi(h^2)(3R-h)
h=height of cap=R(1-cos(theta))
sin(theta)=r/R   theta is an angle formed by h and R in the cap.
H=(V-Vcap)/(pi*r^2)

Use the input command to enter the values for r, R, and V.

TEST your program with the following values: r=30 feet, R=45 feet, and a volume V=120,000 cubic feet



DELIVERABLES:
All spreadsheets and graphs showing data. Matlab script file and output run

EVALUATION:
Six Excel problems   85 points
MatLAB script work: 15 points.