Engr. 126: MATLAB **Question Set #2** **S20**	Name

Go through Chapter 5 (2D Plots+) of the *MatLab Workbook* so that you can learn some of the various 2-dimensional graphing tools in MatLab. **Only __AFTER__ finishing Chapter 5 are you to work on QS #2.** The goal is to **learn MatLab**, not get through the work as fast as possible. Experience has shown me that students get through this Question Set faster if they (1) actually go through Chapter 5 first to learn and practice, and then do the QS, than if they (2) start work on the QS, and then trying to look through QS #5 or online resources to find the "solution."

Remember, the goal of this course is to learn MatLab. The 10 problems in this question set only "test" you on few MatLab features. By going through the workbook, you will learn many more features than I can check you on.

You will be **creating plots** and **printing them out**.

For each plot:

- **Label the axes** with the **axis title** and the **unit of quantity**. For example, if you are plotting spring force versus extension, `F (N)` and `x (m)` would be appropriate axis titles.
- Place a title above the plot (e.g. `Spring Force vs. Extension`), and
- Annotate the plot as necessary using Matlab's text and graphical tools.
- Use the **Text Tool** to put your **name** and **date** at the upper-left corner of the graphic.

When two or more curves are graphed on the same plot, include a legend or directly label each curve (if you directly label each curve, you do not need a legend.

When you are finished with all questions and plots, turn them in as one packet. Remember, QS #1 and 2 must be turned in by the end of the 8th class meeting, not at the end of the semester.

Hint: The `hold` command (Section 5.3.10, Page 60) is an important command when plotting more than one curve on a single graph.

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1. U.S. Population (*Source:* U.S. Bureau of the Census. www.census.gov Accessed Jan. 2013)

The U.S. Population at Census from 1900 to 2010 is given in *Table 1*.

a. Create a vector `y` (or `year`) for the year, and a corresponding vector `pop` for the population.

> Hint: you can use a shortcut to create the year-vector (see "Colon Notation", *Page 33* of workbook).

b. Plot Population vs. Time (population is on the vertical axis).

Do not forget to label each axis: *Population (millions)* and *Year*; title the plot (**U.S. Population vs. Time**); and otherwise annotate your graph, if necessary.

c. Print the graph.

Table 1 U.S. Population, 1900-2010.

Year	Population (millions)
1900	76
1910	92
1920	106
1930	123
1940	132
1950	151
1960	179
1970	203
1980	227
1990	249
2000	281
2010	309

2. Graphical Solution to Roots of a Polynomial

a. Solve *graphically* for the real roots of the following function between $x = -8$ and $x = +8$.

$$f(x) = 1x^4 + 4x^3 - 5x^2 - 6x - 500$$

Do this by plotting the polynomial (see, *Sec.5.6, Page 64*) and graphically finding its roots with the **Data Cursor Tool** ![icon] . Use the Data Cursor to "pick-off" the coordinates of different points on a curve. Get as close to $y = 0$ as possible (since MATLAB) plots points, you will "never" get exactly zero using this method, but you can approximate each root). Remember, a root is the *x*-value that gives $f(x) = 0$.

b. Use the Text Tool to **label the roots** on the plot, e.g., $x = $ ###; $x = $ ####.

c. Print the graph.

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3. Extracting Data from a Matrix, Plotting Two Curves on One Plot

Matrix **P** contains time (seconds), and position (meters) data:

- time is in Column 1,
- the position of Particle A is in Column 2, and
- the position of Particle B is in Column 3.

a. Plot position vs. time for each particle on the same graph. You will need to *extract* columns of data into three vectors.

For this problem, you may connect the data points with straight lines. Use a different line style for each curve (e.g., solid and dashed).

b. Print the graph.

$$\mathbf{P} = \begin{bmatrix} 0 & -1.5 & 2.0 \\ 2 & 1.0 & 2.5 \\ 4 & 2.5 & 3.7 \\ 6 & 4.0 & 5.2 \\ 8 & 4.9 & 7.9 \end{bmatrix}$$

Hint: the time data can be extracted as follows:

`>>t=P(:,1)`   *extracts all rows of 1st column*

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4. Plotting Functions

The two functions below, $a(t)$ and $b(t)$, are typical equations that describe the response of damped oscillating systems; e.g., the vibration of mechanical and/or structural systems, or the oscillation of electrical systems.

$$a(t) = 12e^{-0.6t} \sin(5t + 2)$$

$$b(t) = 8e^{-0.5t} \cos(3t - 4)$$

a. Use the **fplot** command to plot the functions from $t = 0$ to 10 (seconds). Both functions should appear on the same plot. Use different markers, line-styles, etc., for each curve.

b. Label each curve with its equation using the **texlabel** command (*Section 5.3.9 Page 60*); e.g., the labels should look very much like the mathematical equations given above, with the appropriate values in superscript form.

Hint: While we use **exp(x)** function to <u>calculate</u> e^x, when using **texlabel**, we use **e^x** to get the text representation e^x. The command **texlabel('exp(x)')** will give you **exp(x)**, not **e^x**, because MATLAB is working on the text form of *exp(x)*, not on the function.

c. Print the graph.

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5. Small Angle Approximation, Subplots

The small angle approximation for the sine function is: $\sin\theta \sim \theta$, where θ is **theta** and must be in radians. This approximation often simplifies the mathematics of a problem.

Investigate the error in the

a. Create two plots using the **subplot** command. You should have two plots, one above the other. Properly label/title/annotate each plot. Use **texlabel** to represent **theta** as its Greek symbol.

   (1) On the first subplot, plot two curves: **sin(theta)** vs. **theta** and **theta** vs. **theta** for values of **theta** from 0 to 1 (radians). Select an interval ($\Delta\theta$) that makes each curve look smooth.

   (2) On the second subplot, plot *fractional error* vs θ in for values of **theta** from 0 to 1.

   Take the error to be:

$$error = \frac{[\theta - \sin\theta]}{\sin\theta}$$

   Again, the first plot should be directly above the second plot (both horizontal axes have the same variable θ, as well as range of that variable). DO NOT place the plots side-by-side.

   <u>Hint</u>: do not use the example from the workbook, which is for 4 subplots in a 2×2 array. YOUR plot should be 2 subplots tall by 1 subplot wide.

   <u>Hint2</u>: Note that **theta** and **sin(theta)** are both vectors. You cannot perform division on vectors (matrices). How do you get the error at each value of θ?

b. How big can θ be (in radians *and* degrees) so that the error in using the approximation is no more than 5%? Indicate the results on the second subplot using the **Text Tool**. [the added point off this exercise is to show you the error in using the small angle approximation for sign].

c. Print the graph.

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6. Bar Graph

You invest $3,200 at p percent compounded annually. After t years, the value of the investment is:

$$M(t) = 3200(1+p)^t$$

where p in the equation is given in decimal form (e.g., if the growth rate is $p = 5\%$, use $p = 0.05$ in the equation).

a. For $p = 4.0\%$, use a **bar plot** to show your money at the end of each year from 0 to 20 years. Your first data point should be at Year 0 (not 1), with $M = \$3200$.

b. How many years does it take (in whole years) to increase your money at least $5,000? Annotate the answer on the plot using the **Text Tool**.

c. Print the graph.

7. Curve Fitting: Spring Force

In an experiment, a known force is applied to a spring and the spring's elongation is measured. The results for various forces are given in *Table 2*.

Table 2 Force and Elongation of a Spring.

Force F (N)	Spring Elongation x (m)
0	0.000
5	0.014
12	0.033
17	0.042
24	0.064
30	0.082

a. Plot **Force vs. Elongation** (i.e., force is on the vertical axis, elongation is on the horizontal axis). Since the data are from measurements, only plot markers (points); i.e., do not plot a line.

   <u>Do not</u> connect the data points. Experimental data points should not be connected in graphs. In Part (b) you will do a linear curve fit to approximate the response.

b. Use a curve-fit to estimate the spring stiffness. Assume the spring is linear. Include the curve-fit equation on the plot.
   <u>Hint</u>: the stiffness of a spring is $k = \Delta F / \Delta x$.

c. Place a text field on the plot that clearly indicates the stiffness (e.g.: **k = _____ N/m**).

d. Print the graph.

8. Curve Fitting 2: Free Fall

In an experiment, an object is allowed to freefall from rest. The distance it falls is measured every 0.5 seconds. The time and distance data are given in *Table 3*.

a. Plot **d** vs **t** (*d* should be on the vertical axis). Since the data are from measurements, only plot markers.

   <u>Do not</u> connect the data points. Experimental data points should not be connected in graphs. In Part (b) you will do a curve fit to approximate the response.

b. In free-fall without air-resistance, the distance fallen is given by:

$$d = \frac{1}{2} a t^2$$

   where *a* is the acceleration of gravity.

   Use a curve-fit to estimate the acceleration of *a* from the data points. Include the curve-fit equation on the plot.

c. Place a text field on the plot that gives the "experimental" acceleration (**a = _____ ft/sec²**).

d. Print the plot.

e. Enter **hold** (you will be adding a second curve to the graph; see *Section 5.3.10, Page 60*).

f. Plot on the same graph the function (use **hold**):

$$y = \frac{1}{2} g t^2$$

   where $g = 32.2$ ft/sec². This is the theoretical response. (<u>Hint</u>: create a new vector called **y**).

g. Print the new graph with both plots (the data points and its curve fit, and the theoretical function)

h. (*bonus*). In MATLAB, is it possible to force the curve-fit to pass through zero? How?
   (FYI, in Excel, it is possible).

Table 3 Free-fall data.

Time t (sec)	Distance fallen d (ft)
0.0	0.0
0.5	4.0
1.0	15.1
1.5	31.6
2.0	60.2
2.5	96.7

9. Trajectory Problem

The x and y-values of a projectile thrown with initial speed v_o and initial angle a above the horizontal – assuming that the projectile starts at the origin $(x_o, y_o) = (0,0)$ – are:

$$x(t) = (v_o \cos a)\, t$$
$$y(t) = (v_o \sin a)\, t - 0.5 g t^2$$

In S.I. units, g is 9.81 m/s². The time in the air (the time for the projectile to return to $y=0$) is: $t_{air} = \dfrac{2 v_o \sin a}{g}$.

Recall that in MATLAB, the angle argument of a trigonometric function must be in radians. However, in the past few years, MATLAB added a trig functions that allow you to use degrees.

> e.g.: if **b** is the angle in <u>radians</u>, use: **sin(b)**, **cos(b)**, etc.
>   if c is the angle in <u>degrees</u>, use: **sind(c)**, **cosd(c)** ... or **sin(c*pi/180)**

Consider the case when: $v_o = 40.0$ m/s, $a = 30°$ above the horizontal. Assume the ground is level.

a. Calculate the time that the projectile is in the air, t_{air}.

b. Plot the projectile's trajectory (y vs. x). Record the total time in the air on the plot (use the Text Tool).

> Hint: use three vectors, **t30**, **x30** and **y30**. The plot must be "smooth" … so use about 21 points from $t = 0$ to t_{air}.

c. Print the graph.

d. For $v_o = 40.0$ m/s plot the trajectories **for 3 different angles: 30°, 45°, 60°** on the same graph. Label each curve and the time that each projectile is in the air. Do not forget that t_{air} is different for each projectile.

> Hint: since there are three curves, do not use vector names **t**, **x**, **y**. You will continually overwrite the vectors for each angle. For the 30° information, use vectors: t**30**, **x30**, **y30**, for the 45° information: **t45**, **x45**, **y45**, etc.

e. Print the 3-trajectory graph.

f. (*bonus*). Extend **Part (d)** by adding trajectories for 15° and 75°.

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10. PIE Chart

The distribution of majors of sophomore Engineering students at AHC in 2004-2005 was:

Mechanical Engineering:	15
Civil Engineering:	12
Electrical Engineering:	8
Computer Engineering:	5
Environmental Engineering:	2

a. Plot a **pie chart**. Label the pie chart so that the reader knows (at minimum) what major each of the pie slices represents, and the number of students in each slice.

In the title, include the total number of students.

b. Print the graph.