Commands and Functions	
loglog	generates an *x–y* plot with both axes scaled logarithmically
mesh	generates a mesh plot of a surface
meshgrid	places each of two vectors into separate two-dimensional matrices, the size of which is determined by the source vectors
pause	pauses the execution of a program until any key is hit
pcolor	creates a pseudo color plot similar to a contour map
peaks	creates a sample matrix used to demonstrate graphing functions
pie	generates a pie chart
pie3	generates a three-dimensional pie chart
pink	optional colormap used in surface plots
plot	creates an *x–y* plot
plot3	generates a three-dimensional line plot
plotyy	creates a plot with two *y*-axes
polar	creates a polar plot
prism	optional colormap used in surface plots
semilogx	generates an *x–y* plot with the *x*-axis scaled logarithmically
semilogy	generates an *x–y* plot with the *y*-axis scaled logarithmically
shading flat	shades a surface plot with one color per grid section
shading inte:	shades a surface plot by interpolation
sphere	sample function used to demonstrate graphing
spring	optional colormap used in surface plots
subplot	divides the graphics window into sections available for plotting
summer	optional colormap used in surface plots
surf	generates a surface plot
surfc	generates a combination surface and contour plot
text	adds a text box to a graph
title	adds a title to a plot
white	optional colormap used in surface plots
winter	optional colormap used in surface plots
xlabel	adds a label to the *x*-axis
ylabel	adds a label to the *y*-axis
zlabel	adds a label to the *z*-axis

PROBLEMS

Two-Dimensional (*x–y*) Plots

5.1 Create plots of the following functions from $x = 0$ to 10.

(a) $y = e^x$
(b) $y = \sin(x)$
(c) $y = ax^2 + bx + c$, where $a = 5$, $b = 2$, and $c = 4$
(d) $y = \sqrt{x}$

Each of your plots should include a title, an *x*-axis label, a *y*-axis label, and a grid.

5.2 Plot the following set of data:

$$y = \begin{bmatrix} 12, \ 14, \ 12, \ 22, \ 8, \ 9 \end{bmatrix}$$

Allow MATLAB® to use the matrix index number as the parameter for the x-axis.

5.3 Plot the following functions on the same graph for x values from $-\pi$ to π, selecting spacing to create a smooth plot:

$$y_1 = \sin(x)$$
$$y_2 = \sin(2x)$$
$$y_3 = \sin(3x)$$

(*Hint*: Recall that the appropriate MATLAB® syntax for $2x$ is **2 * x.**)

5.4 Adjust the plot created in Problem 5.3 so that:
- Line 1 is red and dashed.
- Line 2 is blue and solid.
- Line 3 is green and dotted.

Do not include markers on any of the graphs. In general, markers are included only on plots of measured data, not for calculated values.

5.5 Adjust the plot created in Problem 5.4 so that the x-axis goes from -6 to $+6$.
- Add a legend.
- Add a text box describing the plots.

x–y Plotting with Projectiles

Use the following information in Problems 5.6 through 5.10:

The distance a projectile travels when fired at an angle θ is a function of time and can be divided into horizontal and vertical distances according to the formulas

$$\text{horizontal}(t) = tV_0 \cos(\theta)$$

and

$$\text{vertical}(t) = tV_0 \sin(\theta) - \tfrac{1}{2}gt^2$$

where

horizontal	=	distance traveled in the x direction
vertical	=	distance traveled in the y direction
V_0	=	initial velocity
g	=	acceleration due to gravity, 9.8 m/s^2
t	=	time, s.

5.6 Suppose the projectile just described is fired at an initial velocity of 100 m/s and a launch angle of $\pi/4$ (45°). Find the distance traveled both horizontally and vertically (in the x and y directions) for times from 0 to 20 s with a spacing of .01 seconds.

(a) Graph horizontal distance versus time.

(b) In a new figure window, plot vertical distance versus time (with time on the x-axis).

Don't forget a title and labels.

5.7 In a new figure window, plot horizontal distance on the x-axis and vertical distance on the y-axis.

5.8 Replot horizontal distance on the x-axis and vertical distance on the y-axis using the comet function. If the plot draws too quickly or too slowly on your computer, adjust the number of time values used in your calculations.

5.9 Calculate three new vectors for each of the vertical (v_1, v_2, v_3) and horizontal (h_1, h_2, h_3) distances traveled, assuming launch angles of $\pi/2$, $\pi/4$, and $\pi/6$.

- In a new figure window, graph horizontal distance on the *x*-axis and vertical distance on the *y*-axis, for all three cases. (You'll have three lines.)
- Make one line solid, one dashed, and one dotted. Add a legend to identify which line is which.

5.10 Re-create the plot from Problem 5.9. This time, create a matrix theta of the three angles, $\pi/2$, $\pi/4$, and $\pi/6$. Use the meshgrid function to create a mesh of theta and the time vector (t). Then use the two new meshed variables you create to recalculate vertical distance (v) and horizontal distance (h) traveled. Each of your results should be a 2001×3 matrix. Use the plot command to plot h on the *x*-axis and v on the *y*-axis.

5.11 A tensile testing machine such as the one shown in Figure P5.11 is used to determine the behavior of materials as they are deformed. In the typical test, a specimen is stretched at a steady rate. The force (load) required to deform the material is measured, as is the resulting deformation. An example set of data measured in one such test is shown in Table P5.11. These data

Figure P5.11

A tensile testing machine is used to measure stress and strain and to characterize the behavior of materials as they are deformed.

Load cell

Extensio-meter

Specimen

Moving crosshead
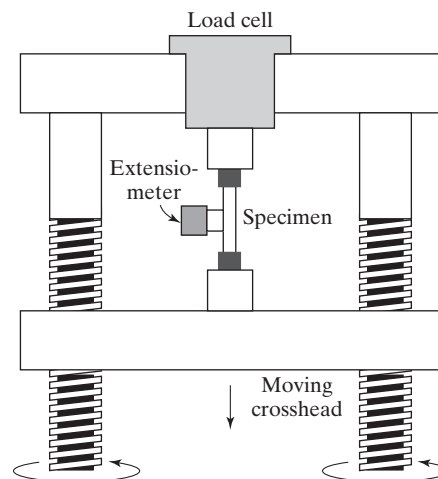
Table P5.11 Tensile Testing Data

load, lbf	length, inches
0	2
1650	2.002
3400	2.004
5200	2.006
6850	2.008
7750	2.010
8650	2.020
9300	2.040
10100	2.080
10400	2.120

(From William Callister, *Materials Science and Engineering, An Introduction,* 5th ed., p. 149.)

can be used to calculate the applied stress and the resulting strain with the following equations.

$$\sigma = \frac{F}{A} \quad \text{and} \quad \varepsilon = \frac{l - l_0}{l_0}$$

where

σ = stress in $lb_f/in.^2$ (psi)
F = applied force in lb_f
A = sample cross-sectional area in $in.^2$
ε = strain in in./in.
l = sample length
l_0 = original sample length

(a) Use the provided data to calculate the stress and the corresponding strain for each data pair. The tested sample was a rod of diameter 0.505 in., so you'll need to find the cross-sectional area to use in your calculations.

(b) Create an *x–y* plot with strain on the *x*-axis and stress on the *y*-axis. Connect the data points with a solid black line, and use circles to mark each data point.

(c) Add a title and appropriate axis labels.

(d) The point where the graph changes from a straight line with a steep slope to a flattened curve is called the yield stress or yield point. This corresponds to a significant change in the material behavior. Before the yield point the material is elastic, returning to its original shape if the load is removed—much like a rubber band. Once the material has been deformed past the yield point, the change in shape becomes permanent and is called plastic deformation. Use a text box to mark the yield point on your graph.

5.12 In the previous chapter, the accumulated cyclone energy index (ACE) was introduced (Problem 4.5). Use that data to solve the following problems. It may also be available to you as an EXCEL spreadsheet, named ace_data. xlsx.

(a) Create an *x–y* plot of the year (on the *x*-axis) versus the ACE index values (on the *y*-axis.)

(b) Calculate the mean ACE value, and use it to draw the mean value on your graph. (*Hint:* You just need two points, one at the first year and another at the final year).

(c) Use the `filter` function to find a running weighted average of the ACE data, over a 10-year period, using the following syntax, assuming you have named the data extracted from the ACE column, `ace`.

```
running_avg_ace = filter(ones(1,10)/10,1,ace);
```

Create a plot of the year (on the *x*-axis) versus the ACE value and the weighted average on the *y*-axis. (You will have two lines.) From your graph, do you think hurricane intensity is increasing? You can find out more about the `filter` function by searching the `help` documentation.

Using Subplots

5.13 In Problem 5.1, you created four plots. Combine these into one figure with four subwindows, using the `subplot` function of MATLAB®.

5.14 In Problems 5.6, 5.7, and 5.9, you created a total of four plots. Combine these into one figure with four subwindows, using the `subplot` function of MATLAB®.

Polar Plots

5.15 Create a vector of angles from 0 to 2π. Use the `polar` plotting function to create graphs of the functions that follow. Remember, polar plots expect the angle and the radius as the two inputs to the `polar` function. Use the `subplot` function to put all four of your graphs in the same figure.

(a) $r = \sin^2(\theta) + \cos^2(\theta)$
(b) $r = \sin(\theta)$
(c) $r = e^{\theta/5}$
(d) $r = \sinh(\theta)$

5.16 In Practice Exercises 5.3, you created a number of interesting shapes in polar coordinates. Use those exercises as a help in creating the following figures:

(a) Create a "flower" with three petals.
(b) Overlay your figure with eight additional petals, half the size of the three original ones.
(c) Create a heart shape.
(d) Create a six-pointed star.
(e) Create a hexagon.

Logarithmic Plots

5.17 When interest is compounded continuously, the following equation represents the growth of your savings:

$$P = P_0 e^{rt}$$

In this equation,

 P = current balance
P_0 = initial balance
 r = growth constant, expressed as a decimal fraction
 t = time invested.

Determine the amount in your account at the end of each year if you invest $1000 at 8% (0.08) for 30 years. (Make a table.)

Create a figure with four subplots. Plot time on the *x*-axis and current balance *P* on the *y*-axis.

(a) In the first quadrant, plot *t* versus *P* in a rectangular coordinate system.
(b) In the second quadrant, plot *t* versus *P*, scaling the *x*-axis logarithmically.
(c) In the third quadrant, plot *t* versus *P*, scaling the *y*-axis logarithmically.
(d) In the fourth quadrant, plot *t* versus *P*, scaling both axes logarithmically.

Which of the four plotting techniques do you think displays the data best?

5.18 According to Moore's law (an observation made in 1965 by Gordon Moore, a cofounder of Intel Corporation; see Figure P5.18), the number of transistors that would fit per square inch on a semiconductor integrated circuit doubles approximately every 2 years. Although Moore's law is often reported as predicting doubling every 18 months, this is incorrect. A colleague of Moore took into account the fact that transistor performance is also improving, and when combined with the increased number of transistors results in doubling of *performance* every 18 months. The year 2005 was the 40th

Figure P5.18
Gordon Moore, a pioneer of the semiconductor industry. (Copyright © 2005 Intel Corporation.)

anniversary of the law. Over the last 40 years, Moore's projection has been consistently met. In 1965, the then state-of-the-art technology allowed for 30 transistors per square inch. Moore's law says that transistor density can be predicted by $d(t) = 30\,(2^{t/2})$, where t is measured in years.

(a) Letting $t = 0$ represent the year 1965 and $t = 46$ represent 2011, use this model to calculate the predicted number of transistors per square inch for the 46 years from 1965 to 2011. Let t increase in increments of 2 years. Display the results in a table with two columns—one for the year and one for the number of transistors.

(b) Using the `subplot` feature, plot the data in a linear x–y plot, a semilog x plot, a semilog y plot, and a log–log plot. Be sure to title the plots and label the axes.

5.19 The total transistor count on integrated circuits produced over the last 35 years is shown in Table P5.19. Create a semilog plot (with the y-axis scaled

Table P5.19 Exponential Increase in Transistor Count on Integrated Circuits*

Processor	Transistor Count	Date of Introduction	Manufacturer
Intel 4004	2300	1971	Intel
Intel 8008	2500	1972	Intel
Intel 8080	4500	1974	Intel
Intel 8088	29000	1979	Intel
Intel 80286	134000	1982	Intel
Intel 80386	275000	1985	Intel
Intel 80486	1200000	1989	Intel
Pentium	3100000	1993	Intel
AMD K5	4300000	1996	AMD
Pentium II	7500000	1997	Intel
AMD K6	8800000	1997	AMD
Pentium III	9500000	1999	Intel
AMD K6-III	21300000	1999	AMD
AMD K7	22000000	1999	AMD
Pentium 4	42000000	2000	Intel
Barton	54300000	2003	AMD
AMD K8	105900000	2003	AMD
Itanium 2	220000000	2003	Intel
Itanium 2 with 9MB cache	592000000	2004	Intel
Cell	241000000	2006	Sony/IBM/Toshiba
Core 2 Duo	291000000	2006	Intel
Core 2 Quad	582000000	2006	Intel
G80	681000000	2006	NVIDIA
POWER6	789000000	2007	IBM
Dual-Core Itanium 2	1700000000	2006	Intel
Quad-Core Itanium Tukwila (processor)[1]	2000000000	2008	Intel
8-Core Xeon Nehalem-EX	2300000000	2010	Intel
10-Core Xeon Westmere-EX	2600000000	2011	Intel

*Data from *Wikipedia*, http://en.wikipedia.org/wiki/Transistor_count.

logarithmically) of the actual data, using circles only to indicate the data points (no lines). Include a second line representing the predicted values using Moore's law, based on the 1971 count as the starting point. Add a legend to your plot.

5.20 Many physical phenomena can be described by the Arrhenius equation. For example, reaction-rate constants for chemical reactions are modeled as

$$k = k_0 e^{(-Q/RT)}$$

where

k_0 = constant with units that depend upon the reaction
Q = activation energy, kJ/kmol
R = ideal gas constant, kJ/kmol K
T = temperature in K.

For a certain chemical reaction, the values of the constants are

$$Q = 1000 \, \text{J/mol}$$
$$k_0 = 10 \, \text{s}^{-1}$$
$$R = 8.314 \, \text{J/mol K}$$

for T from 300 K to 1000 K. Find the values of k. Create the following two graphs of your data in a single figure window:

(a) Plot T on the x-axis and k on the y-axis.

(b) Plot your results as the $\log_{10}$ of k on the y-axis and $1/T$ on the x-axis.

Bar Graphs, Pie Charts, and Histograms

5.21 Let the vector

G = [68, 83, 61, 70, 75, 82, 57, 5, 76, 85, 62, 71, 96, 78, 76, 68, 72, 75, 83, 93]

represent the distribution of final grades in an engineering course.

(a) Use MATLAB® to sort the data and create a bar graph of the scores.

(b) Create a histogram of the scores.

5.22 In the engineering class mentioned in Problem 5.21, there are

2 A's
4 B's
8 C's
4 D's
2 E's

(a) Create a vector of the grade distribution

$$\text{grades} = \begin{bmatrix} 2, & 4, & 8, & 4, & 2 \end{bmatrix}$$

Create a pie chart of the grades vector. Add a legend listing the grade names (A, B, C, etc.)

(b) Use the **menu** text option instead of a legend to add a text box to each slice of pie, and save your modified graph as a **.fig** file.

(c) Create a three-dimensional pie chart of the same data. Earlier versions of MATLAB® had trouble with legends for many three-dimensional figures, so don't be surprised if your legend doesn't match the pie chart.

5.23 The inventory of a certain type of screw in a warehouse at the end of each month is listed in the following table:

	2009	**2010**
January	2345	2343
February	4363	5766
March	3212	4534
April	4565	4719
May	8776	3422
June	7679	2200
July	6532	3454
August	2376	7865
September	2238	6543
October	4509	4508
November	5643	2312
December	1137	4566

Plot the data in a bar graph.

5.24 Use the `randn` function to create 1000 values in a normal (Gaussian) distribution of numbers with a mean of 70 and a standard deviation of 3.5. Create a histogram of the data set you calculated.

Graphs with Two y-Axes

5.25 In the introduction to Problems 5.6 through 5.9, we learned that the equations for the distance traveled by a projectile as a function of time are

$$\text{Horizontal}(t) = tV_0 \cos(\theta)$$
$$\text{Vertical}(t) = tV_0 \sin(\theta) - \tfrac{1}{2}gt^2$$

For time from 0 to 20 s, plot both the horizontal distance versus time and the vertical distance versus time on the same graph, using separate *y*-axes for each line. Assume a launch angle of 45° ($\pi/4$ radians) and an initial velocity of 100 m/s. Assume also that the acceleration due to gravity, *g*, is 9.8 m/s. Be sure to label both *y*-axes.

5.26 If the equation modeling the vertical distance traveled by a projectile as a function of time is

$$\text{Vertical}(t) = tV_0 \sin(\theta) - 1/2 \; gt^2$$

then, from calculus, the velocity in the vertical direction is

$$\text{Velocity}(t) = V_0 \sin(\theta) - gt$$

Create a vector *t* from 0 to 20 s, and calculate both the vertical position and the velocity in the vertical direction, assuming a launch angle θ of $\pi/4$ radians and an initial velocity of 100 m/s. Plot both quantities on the same graph with separate *y*-axes. Be sure to label both *y*-axes.

The velocity should be zero at the point where the projectile is the highest in the vertical direction. Does your graph support this prediction?

5.27 For many metals, deformation changes their physical properties. In a process called *cold work*, metal is intentionally deformed to make it stronger.

The following data tabulate both the strength and ductility of a metal that has been cold worked to different degrees:

Percent Cold Work	Yield Strength, MPa	Ductility, %
10	275	43
15	310	30
20	340	23
25	360	17
30	375	12
40	390	7
50	400	4
60	407	3
68	410	2

Plot these data on a single *x*–*y* plot with two *y*-axes. Be sure to label both *y*-axes.

Three-Dimensional Line Plots

5.28 Create a vector **x** of values from 0 to 20 π, with a spacing of $\pi/100$. Define vectors **y** and **z** as

$$y = x \sin(x)$$

and

$$z = x \cos(x)$$

(a) Create an *x*–*y* plot of **x** and **y**.
(b) Create a polar plot of **x** and **y**.
(c) Create a three-dimensional line plot of **x**, **y**, and **z**. Don't forget a title and labels.

5.29 Figure out how to adjust your input to `plot3` in Problem 5.28 so as to create a graph that looks like a tornado (see Figure P5.29). Use `comet3` instead of `plot3` to create the graph.

Figure P5.29
Tornado plot.
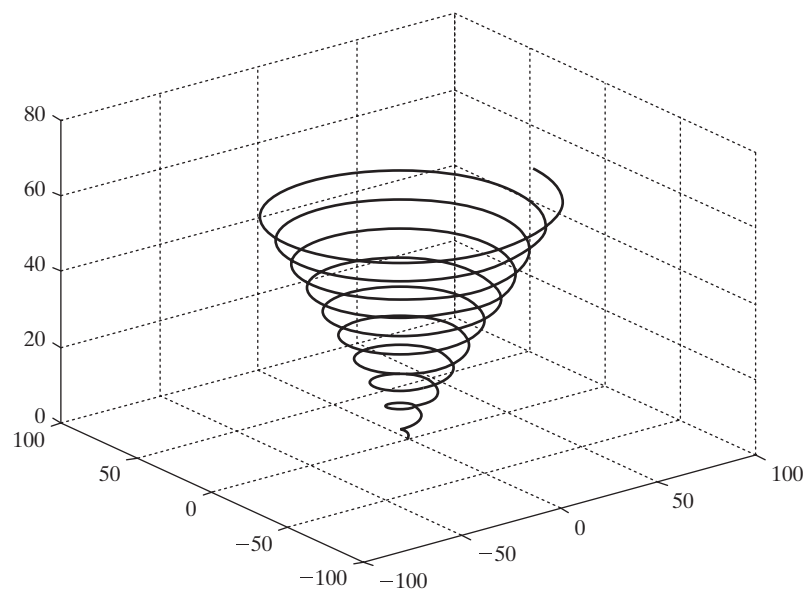
Three-Dimensional Surface and Contour Plots

5.30 Create x and y vectors from −5 to +5 with a spacing of 0.5. Use the mesh-grid function to map x and y onto two new two-dimensional matrices called X and Y. Use your new matrices to calculate vector Z, with magnitude

$$Z = \sin\left(\sqrt{X^2 + Y^2}\right)$$

(a) Use the mesh plotting function to create a three-dimensional plot of Z.

(b) Use the surf plotting function to create a three-dimensional plot of Z. Compare the results you obtain with a single input (Z) with those obtained with inputs for all three dimensions (X, Y, Z).

(c) Modify your surface plot with interpolated shading. Try using different colormaps.

(d) Generate a contour plot of Z.

(e) Generate a combination surface and contour plot of Z.