When writing up your solutions, keep in mind the problem documentation requirements (Slide 6 of the Lecture 1 presentation).

Turn in your homework (typeset, printed, and stapled, with your name, student number, and section) by 12:00 PM on the due date. Homework collection boxes will be in either Prof. Reed’s office or on top of the faculty mailboxes outside the SCUPI main office.

1. (20 points) Text problem 5.13(c). Be sure your plots are properly labeled (variable names and units on the axes, graph title, legend).

2. (20 points) The graph below corresponds to the data on the right:

   ![Graph](image)

   The black curve is a parabola (on semilog plot) that fits the red data points exactly.

   Determine the equation relating \( t \) and \( v(t) \). Verify that your equation predicts the known data.

3. (30 points) In addition to semilog and log-log type plots, you can transform plotted variables to make an equation, or data fitting the equation, appear as a straight line. This technique is powerful as it permits you to determine the parameters of the equation from the slope and intercept.

   For example, suppose you have data you think obeys a physical law of the form
\[ z = a^2 \]

Straightforward algebraic manipulation yields

\[ \log(z) = \log(a) + (b \log(2)) r \]

This has the form of a straight line, \( y = mx + b \), where the independent variable is \( r \) and the dependent variable is \( \log(z) \). A straight line results if you plot \( \log(z) \) on the ordinate and \( r \) on the abscissa. The intercept on the ordinate is \( \log(a) \), and the slope of the line is \( b \log(2) \).

In these equations, \( x \) is the independent variable, \( y \) is the dependent variable, and \( a \) and \( b \) are constants. Determine what you would plot so that the equation appears as a straight line, and how you would determine the constant values \( a \) and \( b \) from the plot.

1) \( y = (ax + b)^{-2} \)
2) \( y = (ax + b)^2 + 5 \)
3) \( y = [3 + \left( a \exp\left(\frac{b}{x-4}\right)\right)]^{-2} \)
4) \( \sin(y) = ax^b \)
5) \( y = 4 - \frac{1}{ax^b} \)

4. (30 points) Consider a chemical reaction

\[ A + B \overset{k}{\rightarrow} C \]

where molecules A and B react to form molecular product C. In general, the rate of the reaction, \( k \), depends strongly on temperature according to the Arrhenius equation

\[ k = k_0 e^{-\frac{E_a}{k_BT}} \]

where

- \( k \) is the reaction rate in \( s^{-1} \) (molecules per second)
- \( k_0 \) is the frequency factor of the reaction (also in \( s^{-1} \))
- \( k_B \) is Boltzmann’s constant
- \( T \) is the temperature in K
- \( E_o \) is the activation energy of the reaction
The quantity $E_a$ is a measure of how much energy is needed for the reaction to occur. Measurements of activation energy are useful in quantifying the strength of chemical bonds.

Suppose an experiment is performed to measure $k$ at several temperatures. First, show mathematically that $E_a$ can be determined by plotting $\log(k)$ against $1/T$.

The table shows the result of such an experiment:

<table>
<thead>
<tr>
<th>Temperature, K</th>
<th>Reaction rate, s$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>298</td>
<td>$1.74 \times 10^{-5}$</td>
</tr>
<tr>
<td>308</td>
<td>$6.61 \times 10^{-5}$</td>
</tr>
<tr>
<td>318</td>
<td>$2.51 \times 10^{-4}$</td>
</tr>
<tr>
<td>328</td>
<td>$7.59 \times 10^{-4}$</td>
</tr>
<tr>
<td>338</td>
<td>$2.40 \times 10^{-3}$</td>
</tr>
</tbody>
</table>

Use Matlab to plot $\log(k(T))$ against $1/T$. (Use linear axes for the graph.)

In the Matlab Figure editing window, select Tools > Basic Fitting to fit a line to the data. (Check the “Show Equations” box to get the equation of the line.) Use the fitted line to determine the activation energy $E_a$. Your answer should have units of eV (electron volts).

Include a copy of the Matlab plot in your solution.

Hints:
The common (base 10) logarithm function in Matlab is called log10. If T is a column vector, $1/T$ will not give another column vector. You should instead use the rdivide operator (look it up in the Matlab documentation).

**Preparation for Next Week**

Read Chapter 6 in Eide

Read and understand these wikipedia articles: