Nonlinear Least Squares Solutions V3

Diode Solutions

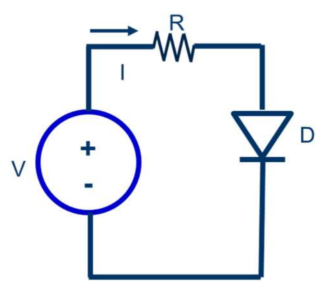
Useful References:

At the end of this exercise you will be able to:

- Solve a problem using an iterative solution
- Extract a parameter model for a device or system to match given data
- Solve using a system of equations, and find the root solution

Diodes solutions require iterative and nonlinear solvers. Let's first consider the most basic diode problem. We can model a diode with this equation $I = I_s\left(e^{qV/nkT} - 1\right)$(Eq.1). The complication comes when you place this diode in a circuit. Consider the case where the diode is in series with a resistor R. The current voltage relationship is, of course, Ohm's Law, V=IR. Note that I is on both sides of the equation suggesting several ways to solve it. We will solve using the diode equation above and nodal analysis using the circuit below.

$$I = I_s\left(e^{(V-IR)q/nkT} - 1\right)$$



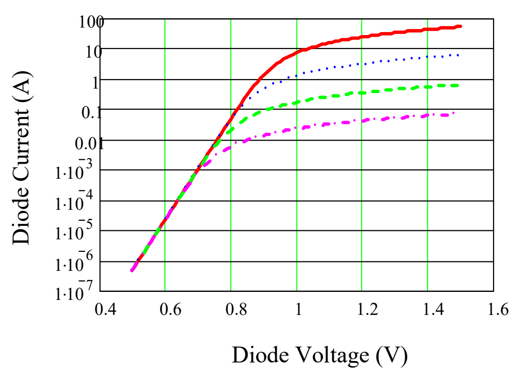


Figure 1

These plots show several different resistances, but your answer will look different.

We will write some code in class to get you started with each of these problems.

Problem 1: Next determine the current I thorough the circuit in Figure 1 by doing a nodal analysis for the circuit and using the current through the diode defined by the diode equation Eq.1. Then solve using optimize.fsolve finding the solution voltage across the diode. Using these parameters for the diode, Is=1e-9, n=1.5, R=10k ohms, T = 350 and applied voltage V from 0.1 to 2.5 V. Print V and I and plot log(I) vs V, label axes, and show with a grid. Turn in your code file, and capture images to a Powerpoint file. Label all images in the Powerpoint file and save as pdf.

Your method is to write the equation using nodal analysis for the node connecting the resistor and the diode, and then write the current equation for the diode in terms of the voltage across it. This should be something like

$Err = \frac{V_d}{R} - \frac{V}{R} + Idiode(V_d)$, where Err should be zero when the value for V_d, the voltage across the diode is correctly chosen.

Problem 2: We are going to repeat the diode problem above for a more diode where the parameters not known. The function for this diode is shown below.

```
def DiodeI(Vd,A,phi,n,T):
   k = 1.38e-23
   q = 1.6e-19
   Vt = n*k*T/q
   Is = A*T*T*np.exp(-phi*q/(k*T))
   return Is*(np.exp(Vd/Vt)-1)
```

Where phi is the barrier height, T is the temperature, R is the lead resistance, A is the cross-sectional area of the diode, n is the ideality, and Vd is the voltage across the diode(applied to the diode)

a) Assume this diode is placed in the circuit in Figure 1 where the lead resistance R is included. Using the methods you developed in problem 2 create a function that returns the currents through this diode for supplied voltage Vs (where Vs is an array of voltages). The returned current should also be an array. In this function you will solve for the current at each supplied voltage and return the array of currents.

b) You are supplied a two datasets named DiodeIV.txt and DiodeIV_nonoise.txt. The objective is to find the diode parameters. This is a diode which may have uncommon material parameter values. You will be given A, and T, of the measured data and you must determine the other parameters n, phi, and R.

.

Try using scipy optimize leastsq, which will require you optimize one parameter at a time, iteratively until the solution is achieved.

- from scipy import optimize
- and then use optimize.leastsq(…

Read the DiodeIV.txt (or DiodeIV_nonoise.txt). This file contains two columns of data. The first column is the source voltage, the voltage across the diode and resistor, and the diode current. The Area is 1e-8 and the temperature is 375 Kelvin. Try an initial value of Phi of 0.8, an initial Ideality of 1.5, and an initial Resistor value of 10000 ohms. Your objective is to find the actual value for Phi, Ideality, and the Resistor.

Your objective is that you find parameters that will give you the same currents given source voltage as the ones you read in from the file. To do this you will have to solve for the voltage across the diode, then calculate the diode current for an set of parameters. Then optimize the values of these parameters to give the same currents as a function of source voltage as those in the file.

To do this you will have to write a function that calculates the residual error. Consider returning absolute or normalized error from the residual function which helps fit the low amplitude parts of the curve as wall as the high bias parts. It looks something like this:

Absolute Error = (ynew-ylast)

Normalized Error = (ynew-ylast+1e30)/(ynew+ylast+1e-30)

You may also want to find the errors in logs of currents rather than actual currents.

If you use optimize.leastsq the first parameter will be the residual function and the second will be the guess of the parameter you are trying to find. This is then the first parameter in that residual function. Since you are optimizing three parameters you may want to write identical residual functions with n, phi, and R as the first parameter to facilitate this process.

Then you could optimize them something like this:

```
while (err>tolerance and iteration<niter):
    phi = optimize.leastsq(residualp, phi, all the other parameters including n and R)
    n = optimize.leastsq(residualn, n, all the other parameters including n and R)
    R = optimize.leastsq(residualR, R, all the other parameters including n and R)
```

Err calculation is up to you. A good choice is the difference between the parameters in each pass. When the parameters stop changing you might want to stop. You probably want to limit the number of times through the loop to prevent an infinite loop in the case where your code doesn’t converge.

Also, build this one step at a time test each step before continuing.

For all problems submit all codes and as well answers and plots requested.