NAME:

Question 1 (15PTS):

You have an abrupt junction diode with NA=ND=10^{15}cm^{-3} made out of Silicon. What is the maximum temperature that this diode will operate like a diode? Justify your answer.

In order to have a diode one needs a pn junction. In order to have a pn junction the semiconductor has to be doped p or n type. As the temperature increases, so does ni, when ni equals the doping concentration the material turns intrinsic. At this point there is no p or n region in the semiconductor, thus no pn junction and thus no diode.

Given that one can solve for temperature in the ni equation analytically:

$$n_i := 3.1\cdot 10^{16}\,\frac{\mathrm{cm}^{-3}}{\mathrm{K}^{1.5}}\cdot T^{1.5}\cdot e^{\left(-.603\mathrm{V}\cdot\frac{q}{k\cdot T}\right)} \qquad n_i = 1.221\times 10^{10}\,\mathrm{cm}^{-3}$$

One would use a chart or plot out where ni equaled the lowest doping concentration. Using the chart 550K is where this happens.

Question 2(15pts):

You need to design a diode that will work at extremely high temperatures. Select a semiconductor that would be the best candidate for high temperature operation. Justify your answer.

Given that the question did not mention the light properties of the diode, the material could be direct or indirect.

From the last problem material top being n or p type when ni approaches the lowest doping level. Since ni is inversely dependant on bandgap, the largest band gap will produce the lowest ni, and thus will be possibly suited for high temperature operation.

From appendix F SiC, ZnSe GaN all have large bandgaps so could be candidates. What is not shown is how tightly bound the material is. Some materials can not be raised to high temperatures without melting. GaN and SiC and Diamond are good high temperature semiconductor materials.

Question 3 (20pts):

Design a Silicon P+/n Diode with a breakdown voltage of 100Volts. Explain your answer. You need to pick NA and ND.

From the chart (fig 29) NB should be $5x10^{15}cm^{-3}$. In this case ND=NB, and to have W=Xn, NA=100*ND=$5x10^{17}cm^{-3}$.

Question 4 (15pts):

What is the temperature dependence of the capacitance of an abrupt silicon p/n junction?

$$C_j = \left[\frac{q \cdot \varepsilon_s \cdot N_B}{2 \cdot (V_{bi} - V)}\right]^{\frac{1}{2}} \qquad V_{bi} = \frac{k \cdot T}{q} \cdot \ln\left(\frac{N_A \cdot N_B}{n_i^2}\right)$$

$$V_{bi} = \frac{k \cdot T}{2q} \cdot \ln\left(\frac{N_A \cdot N_B}{n_i}\right)$$

$$V_{bi} = \frac{k \cdot T}{2q} \cdot \ln\left(\frac{N_A \cdot N_B}{3.16 \cdot 10^{16} \cdot T^{1.5} \cdot e^{\frac{-E_g \cdot q}{2 \cdot k \cdot T}}}\right)$$

$$V_{bi} = \frac{k \cdot T \cdot E_g \cdot q}{2q \cdot 2 \cdot k \cdot T} \cdot \ln\left(\frac{N_A \cdot N_B}{3.16 \cdot 10^{16} \cdot T^{1.5}}\right)$$

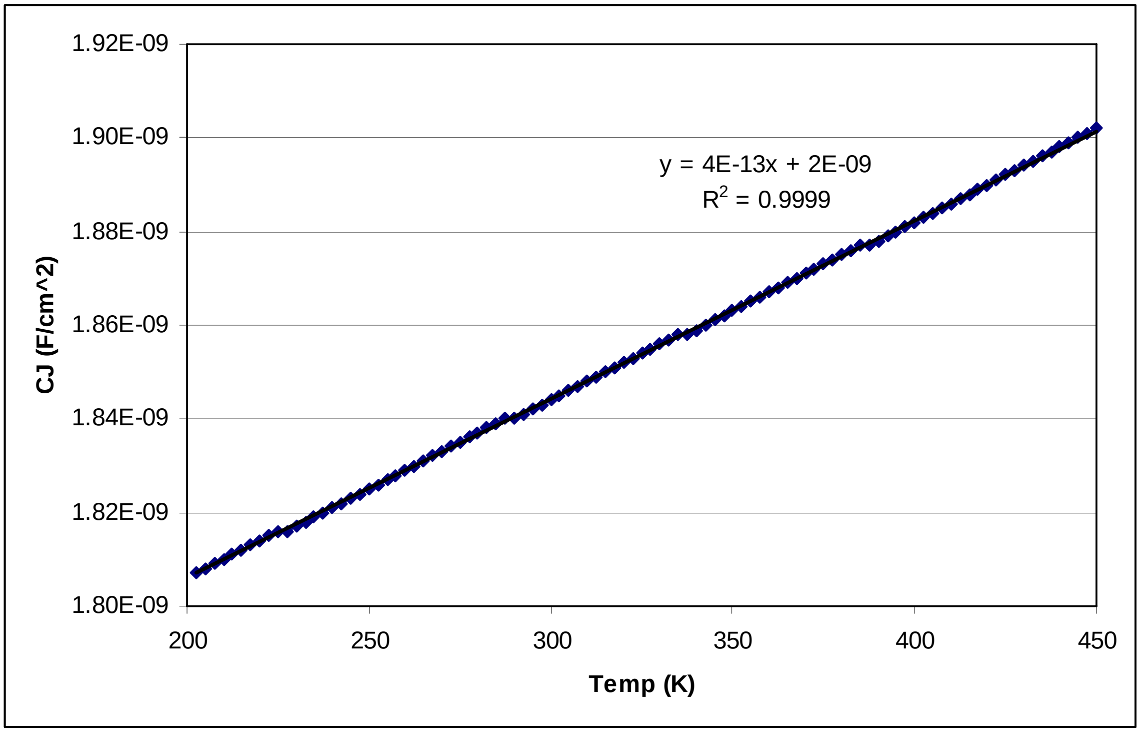
$$V_{bi} = \frac{E_g}{4} \cdot \ln\left(\frac{N_A \cdot N_B}{3.16 \cdot 10^{16} \cdot T^{1.5}}\right)$$

$$V_{bi} = \frac{E_g}{4 \cdot 1.5} \cdot \ln\left(\frac{N_A \cdot N_B}{3.16 \cdot 10^{16} \cdot T}\right)$$

$$C_j = \left(\frac{3\, q \cdot \varepsilon_s \cdot N_B}{E_{g0} - \frac{\alpha \cdot T^2}{T + \beta}}\right)^{\frac{1}{2}} \cdot \frac{1}{\ln\left(\frac{N_A \cdot N_B}{2 \cdot 3.16 \cdot 10^{16} \cdot T}\right)}$$

If we plot this out it actually extracts very close to linear. Notice though that the slope is ~10^-13. The CJ does not vary by more than 6% over the whole range.

NAME:


y = 4E-13x + 2E-09
R2 = 0.9999
CJ (F/cm^2)
1.92E-09
1.90E-09
1.88E-09
1.86E-09
1.84E-09
1.82E-09
1.80E-09
200
250
300
350
400
450
Temp (K)

NAME:

Question 5(25pts):

Draw the Energy Band Diagram of a Silicon N+/P junction at thermal equilibrium if NA=10^{16}cm^{-3} and ND= 10^{18}cm^{-3} at 200K. Show numerical values for Vbi, W, and Eg

Assume all donors/acceptors are ionized.

Draw a EGB of a diode with these parameters:

Eg=1.147eV
ni=5.21x10^{4}cm^{-3}
W=.356um
Vbi=.972
EFp=.448eV
EFn=.528eV

Question 6(10pts):

Please Extract IS, n, and Rs from the data below. Show method.
There is only one diode. Each chart shows a different part of the same IV curve.

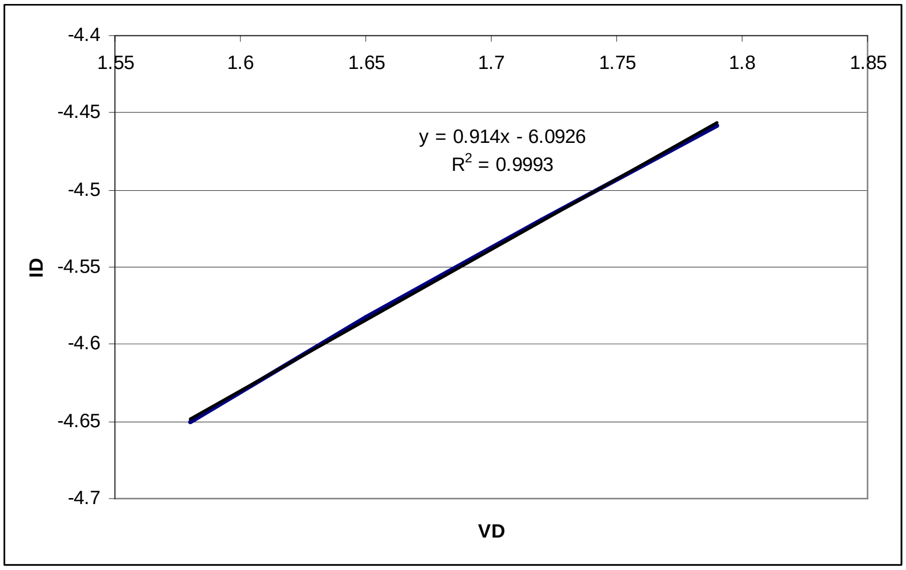


Figure 1: Fake graph Don't use.,

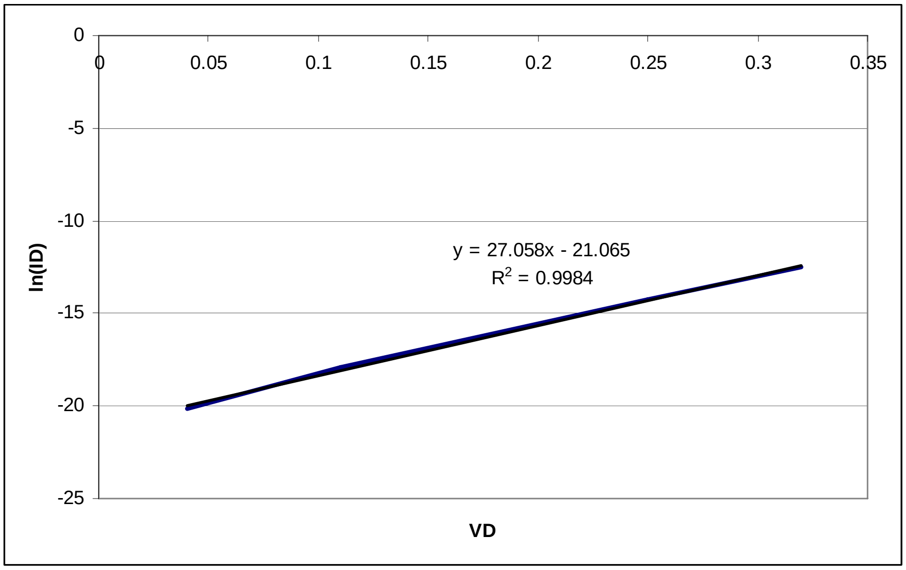


Figure 2:extract Is and n.

$$I_s := e^{-21.065} \quad I_s = 7.105 \times 10^{-10}$$

$$n := \frac{1}{.0259 \cdot 27.058} \qquad n = 1.427$$

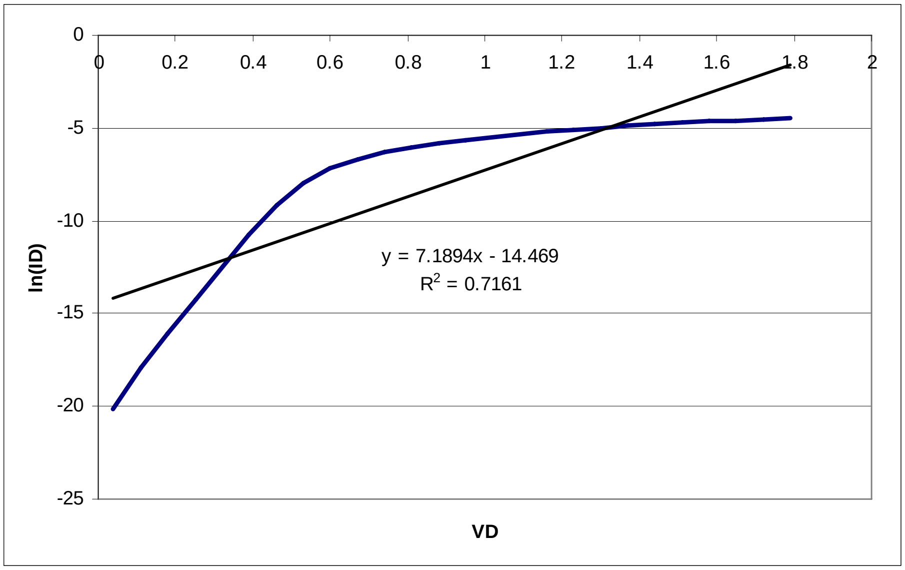


Figure 3: fake.

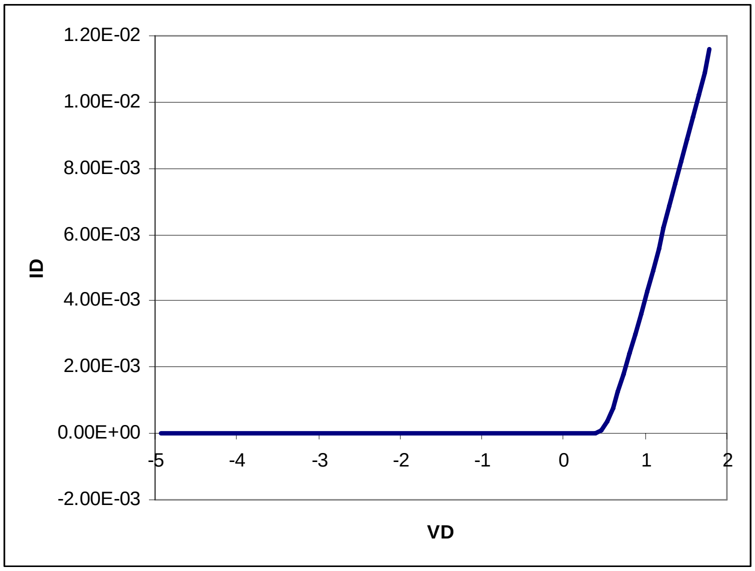


Figure 4: use for rs.

$$m := \frac{(9-6)\cdot 10^{-3}\,A}{(1.5-1)\,V}$$

$$m = 6 \times 10^{-3}\,\frac{1}{\Omega} \qquad R_s := \frac{1}{m} \qquad R_s = 166.667\,\Omega$$