EECS 2077
Semiconductor Devices

4 Diode Currents

Name:______________________________ **Complete** ____

Reminders

(1) ★ will mark areas where we will stop until we agree upon the solution as a group, or until I check your answer. If your group gets done early, then you may move onto problems near the end that we might not complete during class.

(2) When you are done and I have approved, erase all your work on the wall/board. Clean up! No food or drink other than water please.

In-Class Problems

(1) The I-V diagram of an ideal PN junction is shown at right. For each of the three points labeled on the curve (1, 2, 3) provide the following:

(a) a simplified version of the diode equation for each point

(b) band-diagram showing with where the current components originate from

(c) a short description of the forces that drive each current component, and which current component dominates (if any)

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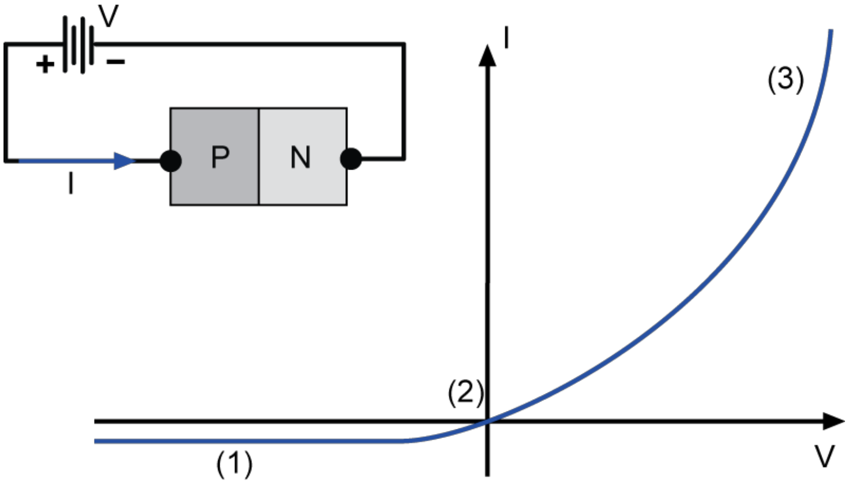
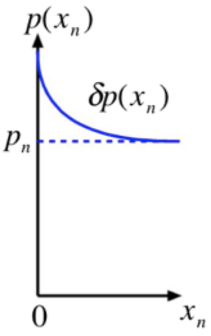
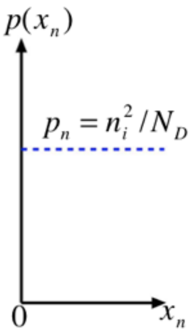


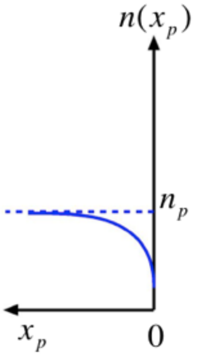
(2) Below is a plot of carrier concentration on either side of a diode, under various bias conditions. You should be able to answer these questions and fully understand them!



(plot 1)



(plot 2)



(plot 3)

(a) the three plots

__ are for minority carriers ONLY

__ are for majority carriers ONLY

__ include both

(b) label each item below as plot 1, plot 2, or plot 3:

__ an excess at the depletion edge (X=0) because of forward bias and diffusion

__ zero concentration at the depletion edge (X=0) because of reverse bias and drift

__ no concentration change because drift and diffusion currents balance at 0V for a diode ★

(3) You increase doping for a diode, the how does the FORWARD current change and WHY. Don't just refer to the equation, explain it based on drift/diffusion, generation, energy barriers, etc. ONE SENTENCE MAX!

(4) You increase doping for a diode, the how does the REVERSE current change and WHY. Don't just refer to the equation, explain it based on drift/diffusion, generation, energy barriers, etc. ONE SENTENCE MAX!

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(5) [20 pts] An <u>ideal</u> Si p+n junction at 300K has the following parameters (you may or may not need them all).

<u>p-side:</u>	**<u>n-side:</u>**	**<u>General parameters</u>**
$N_a=10^{17}/cm^3$	**$N_d=10^{15}/cm^3$**	**$A=10^{-4}$ cm^2**
$D_n=18$ cm$^{2/}$sec	**$D_p=25$ cm$^{2/}$sec**	**$\varepsilon_{Si}=11.8$**
$L_n=10^{-3}$ cm	**$L_p=10^{-2}$ cm**	

(a) What is the <u>drift current</u> across the junction at an applied <u>reverse bias of -3V</u>?

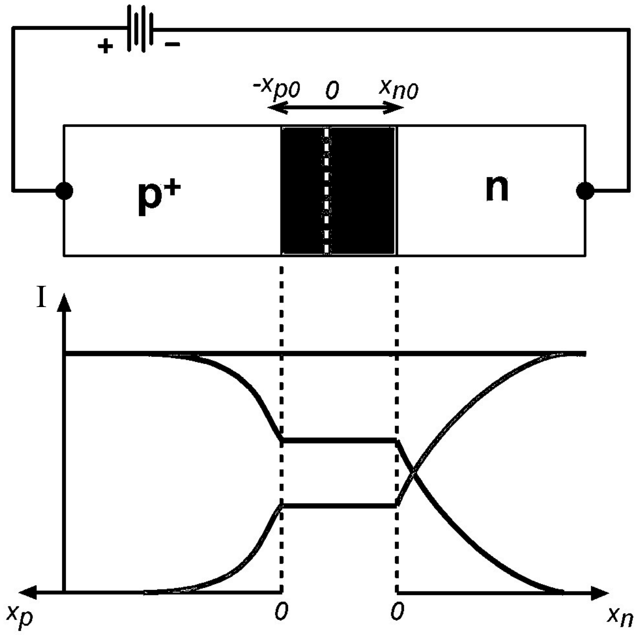
(b) What is the <u>diffusion current</u> across the junction at a <u>reverse bias of -3V</u>? ★

(c) What is the <u>diffusion current</u> across the junction at a <u>forward bias of 0.7? V</u>?

(d) What is the <u>drift current</u> across the junction at a <u>forward bias of 0.7? V</u>? ★

<u>Extra Problems (if you have time, finish during class when I can help, or on your own time)</u>

(6) Two-part question related to this plot of hole current, electron current, and total current. First, why are the electron and hole currents not constant in the p-type and n-type regions? Second, why are they constant inside the depletion region?



(7) Why does the ideal diode equation give constant current under reverse bias? 1-2 sentences MAX.

(8) Use MATLAB to visualize effects of doping on diode current (from Pierret Ex. 6.5). Play around with the code a bit. When you enter doping levels at the "ND= " prompt, put the input in square brackets and separated by spaces (1D array of data). A useful range may be several values from 1e+16 to 1e+17 for doping.

```
%Variation of Ideal-Diode I-V  with semiconductor
doping.
%Si step junction, T = 300K.
%In response to the "ND=" prompt type [ND1 ND2 ...] to
input
%multiple doping values.
%Initialization and Universal Constants
clear

k=8.617e-5;
q=1.6e-19;
%Device, Material, and System Parameters
A=1.0e-4;
ni=1.0e10;
taup=1.0e-6;
ND=input('Input the n-side doping concentration, ND = ');
T=300;
%Hole Mobility Calculation
NAref=2.35e17;
upmin=54.3;
up0=406.9;
ap=0.88;
up=upmin+up0./(1+(ND./NAref).^ap);
%The mobility calculation here assumes the hole
minority carrier
  %mobility is equal to the hole majority carrier mobility.
%I-V Calculation
VA=linspace(-1,0.2);
DP=k.*T.*up;
LP=sqrt(DP.*taup);
I0=q.*A.*(DP./LP).*(ni^2 ./ND)
I=I0.'*(exp(VA./(k.*T))-1);
%Plotting Result
close
plot(VA,I); grid;
ymin=-2*I0(1);  ymax=5*I0(1);
axis([-1,0.2,ymin,ymax]);
xlabel('VA (volts)');  ylabel('I (amps)');
%Adding axes,key
xx=[-1 0.2];  yx=[0 0];
xy=[0 0]; yy=[ymin,ymax];
hold on
plot(xx,yx,'-w',xy,yy,'-w');
j=length(ND);
for i=1:j;
   yput=(0.70-0.06*i)*ymax;
   yk(i,1)=yput; yk(i,2)=yput;
   text(-0.68,(0.69-
0.06*i)*ymax,['ND=',num2str(ND(i)),'/cm3']);
end
xk=[-0.8 -0.7];
plot(xk,yk);
text(-0.74,0.75*ymax,'Si, 300K');
hold off
```