EECS 2077
Semiconductor Devices

3 Contact Potential

Name:____________________________ Complete ____

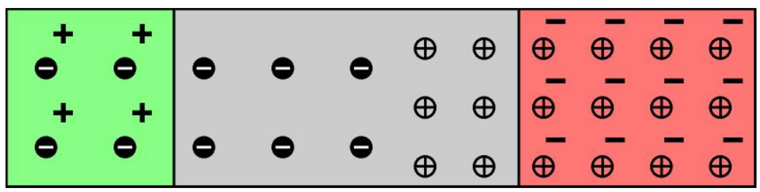
Reminders

(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) Draw the two blocks of semiconductor shown below (you don't need to draw all the charges inside, just 1 colored rectangle for each block. Draw it WIDE and higher up on the board, as you will need to draw underneath it too.



(a) label where the two blocks were joined with a black vertical line.

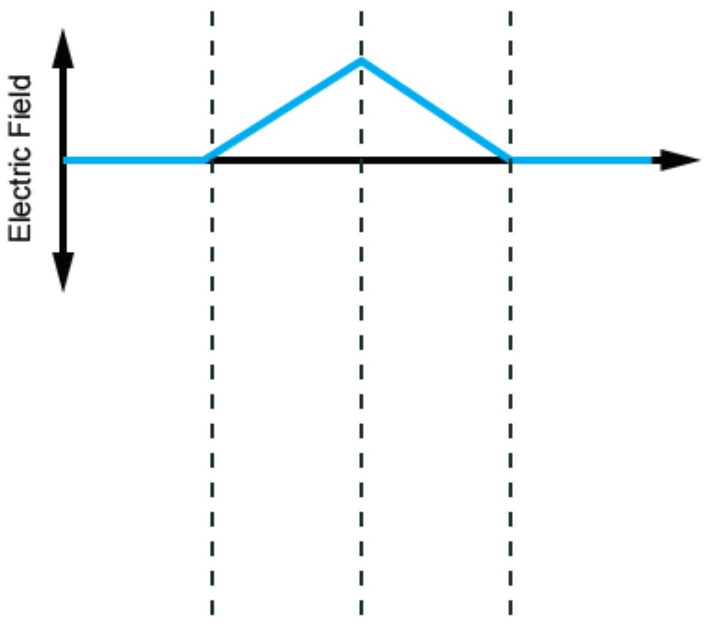
(b) label each block as either: 'Phosphorus atoms and free carriers ' / 'Boron atoms and free carriers' / 'Boron atoms only' / 'Phosphorous atoms only'

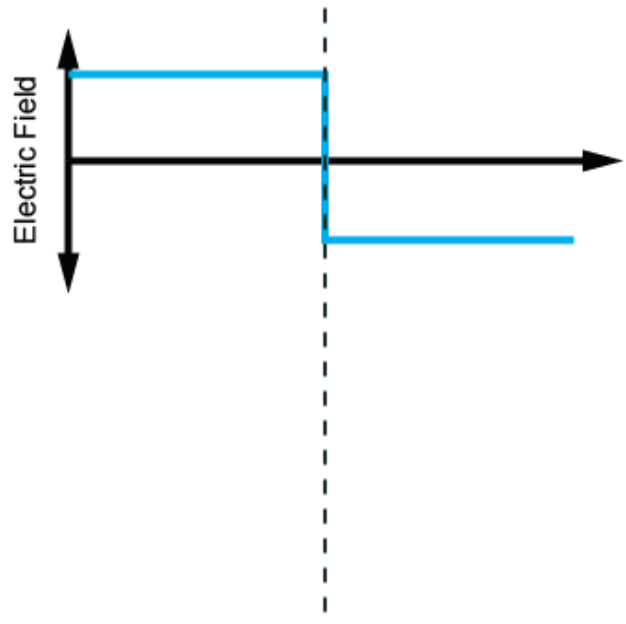
(c) label locations where you get 'maximum E-field' and 'zero E-field' and make sure you understand why.

(d) draw a band-diagram underneath this, extending vertical dotted lines down for the edges of the depletion region, and extending down the vertical line for where the blocks were, such that they all go through your band-diagram. Label Ec/Ev/Ef on the diagram. Make sure EVERYTHING in the diagram represents un-equal dopings, including the Fermi-level distances from the bands. ★

Instructor – Prof. Jason Heikenfeld

(2) E-field causes band diagrams to have slope! Anytime you have E-field, you know it means the bands must bend! Redraw each E-field plot on the board, and below the E-field plots draw the corresponding band diagrams (don't worry about the Ef or dopings, just plot the conduction and valence bands). To help solve this problem, use the electrons=water and holes=bubbles analogy and think how they each should move (left or right) in the E-field. Assume the E-field is measured in the direction from left to right. Remember, higher E-field should make the bands slope steeper! ★





(3) Questions related to potential across a diode…

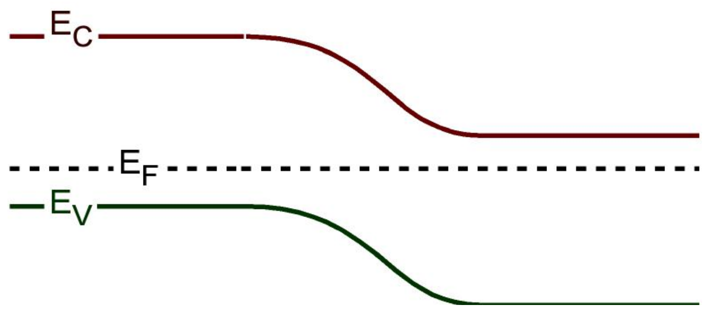
(a) Calculate the total amount of band-bending (<u>energy, E</u>) that would be achieved for a PN junction, <u>in units of eV</u>, for a diode that is doped 10^{17}/cc p-type and 10^{15}/cc n-type. *Hint, calculate for volts, then change it to units of eV. Is simple, for example 1 V will turn into 1 eV. Another hint, at 300K thermal voltage is always 0.0259 V, so you don't need to calculate that part of the equation.*

(b) [5 pts] On what side would most of the most of the depletion width occur?

(c) [5 pts] If +0.3 V is added to the n-side while the p-side is grounded, what will be the new total amount of band-bending (in eV)? We have not done this in class, but just think about it… answer is simple (think how bands would bend).

(c) A diode has internal contact potential. If you hooked a diode up w/ a wire loop to connect the n and p-sides with the wire, would the internal voltage cause current to continue to flow through the wire? ★

(4) Draw the band shown below and then:



(a) add electrons and holes where you think they should be, and try to show the concentrations you expect (for example, maybe 10-12 carriers for majority carriers, and may only 2-3 for minority carriers).

(b) draw with a line-path and arrow-head at the end, the starting point, path, and destination for electron drift current
(c) draw with a line-path and arrow-head at the end, the starting point, path, and destination for electron diffusion current
(d) draw with a line-path and arrow-head at the end, the starting point, path, and destination for hole drift current
(e) draw with a line-path and arrow-head at the end, the starting point, path, and destination for hole diffusion current ★

(5) Last question, <u>a repeat from last week because this is very important</u>, again, figure out how a diode works on your own before I even teach you! A diode is rectifying, meaning it gives you very small (nearly zero) current in one direction (voltage polarity) and large current in the other direction (voltage polarity).

(a) for the case of negative voltage applied to the p-side and the n-side grounded, re-draw the conduction and valence bands (don't worry about drawing the Fermi level). Then draw and label the resulting current as dominated by drift or diffusion (only one will dominate) and if it is large or small (think of number of carriers feeding the resulting current, are they majority or minority carriers?).

(b) for the case of positive voltage applied to the p-side and the n-side grounded, re-draw the conduction and valence bands (don't worry about drawing the Fermi level). Then draw and label the resulting current as dominated by drift or diffusion (only one will dominate) and if it is large or small (think of number of carriers feeding the resulting current, are they majority or minority carriers?). ★

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

(6) The drift current for a diode at thermal equilibrium originates from (choose one of the following):

__ minority carriers that are thermally generated NEAR the depletion region edge and swept across by E-field

__ majority carriers that are thermally generated NEAR the depletion region edge and swept across by E-field

__ minority carriers that are from dopants NEAR the depletion region edge and swept across by E-field

__ majority carriers that are from dopants NEAR the depletion region edge and swept across by E-field

(7) Some review… A slab of semiconductor with a mobility of 1000 (cm/s)/(V/cm) or cm^2/V-s, is setup at steady state to have electrons injected at one side and removed from the other side such that on one side there are 10^{17} electrons and on the other side there are 10^7 electrons. Assume the semiconductor slab is 0.01 cm long (100 μm). Calculate the resulting diffusion current density (A/cm^2). Reminder, thermal voltage is 0.0259 V at 300K.