EECS170A Fall 2004 **Final Exam** Name:__________________________

12-07-2004 ID no.:__________________________

Sec.B: Peter Burke 4 to 6 pm

1	2	3	4	5	Total
/5	/5	/5	/5	/5	/45

FIVE PROBLEMS TOTAL. DO NOT ASSUME YOU WILL GET PARTIAL CREDIT.

DO NOT BEGIN THE EXAM UNTIL YOU ARE TOLD TO DO SO.

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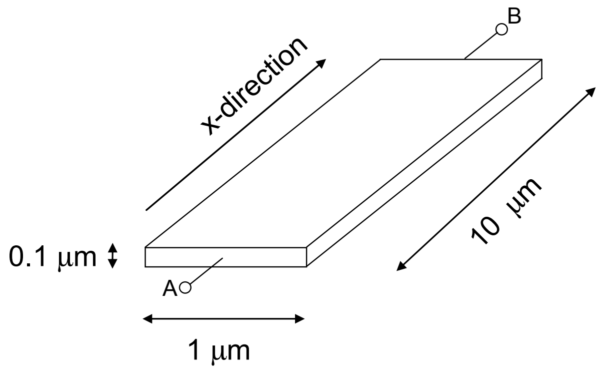
PROBLEM ONE: (5 points)

For a piece of Si at 300 K, there is no doping, in other words it is *intrinsic*.
Find the resistivity to within 10%. (Hint: find the density of electrons and mobility first, then calculate the resistivity.)

$n = p = n_i$ since this is an intrinsic material with no doping
$\mu_n = 1358\ cm^2/V\text{-}s$
$\mu_p = 461\ cm^2/V\text{-}s$
$\rho = 1/[q(\mu_n n + \mu_p p)]$
$= 1/[q(\mu_n n_i + \mu_p n_i)]$
$= 1/[qn_i(\mu_n + \mu_p)]$
$= 1/[(1.6x10^{-19}C)(10^{10}cm^{-3})(1358\ cm^2/V\text{-}s + 461\ cm^2/V\text{-}s)]$
$= 3.43x10^{11}\ \mu\Omega\text{-}cm$
Acceptable Range: $3.1\text{-}3.7\ x10^{11}\ \mu\Omega\text{-}cm$

Grading Criteria:
1 point if p, n, μ_n, and μ_p correct
1 point for correct ρ equation
3 points for correct answer within range

PROBLEM TWO: (5 points)



Consider the piece of Si above.
At x=0 (which is the "A" end), the electron density is 10^{14} cm^{-3}.
At x=10 µm (which is the "B" end), the electron density is 0 cm^{3}.
The electron density varies linearly with x in between.
Assume the electric field is zero everywhere inside.
Approximate D_N=35 cm^2/s.
Calculate the electron current density and current in the x-direction.
Make sure to get the sign correct.
If you say there is positive current, you mean current flows in the direction of the arrow in the figure.
(Hint: Is the current due to drift or diffusion?)

(Current is due to diffucsion since the electric field is equal to zero)
$J_N = qD_N\, dn/dx$
$= (1.6x10^{-19}C)(35cm^2/s)(-10^{14}cm^{03})/(10\mu m\ x10^{-4}cm/\mu m)$
$= -.56A\text{-}cm^{-2}$
Acceptable Range: 0.50 - 0.60 a-cm^{-2}
$I = JA$
$= (-.56A\text{-}cm^{-2})(1\mu m\ x10^{-4}cm/\mu m)(0.1\mu m\ x10^{-4}cm/\mu m)$
$= -5.6x10^{-10}A$
Acceptable Range: 0.50 – 0.60 nA

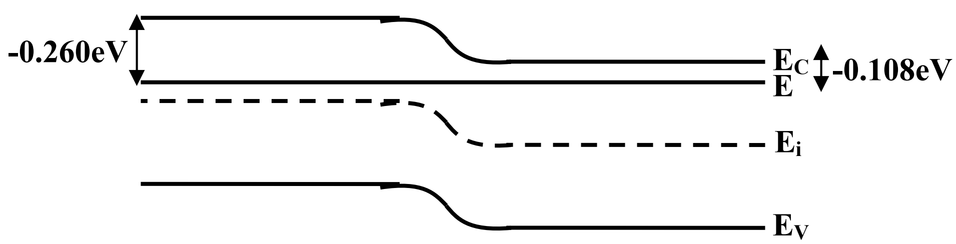
Grading Criteria:
1 point for correct current density equation
1 point for plugging in the numbers correctly into the current density equation, including the minus sign
1 point for correct current density within the given range
1 point for correct current equation
1 point for correct current equation within range

PROBLEM THREE: (5 points)

Consider an n-n junction with an abrupt doping profile. The doping level on the left hand side is 10^{15} cm^{-3}, and on the right hand side it $5x0^{17}$ cm^{-3}. Assume equilibrium conditions below.

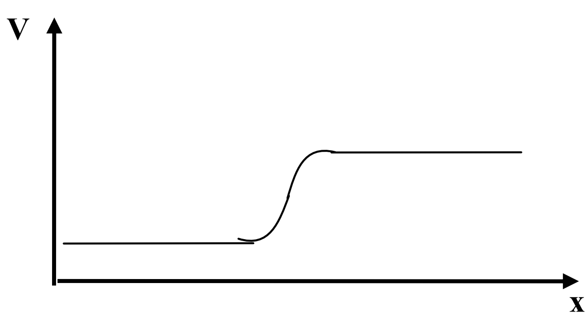
a) Draw the energy band diagram for the junction. Make sure you calculate E_f-E_c on both sides of the junction and label it on the diagram.

$E_F - E_C = kT\ ln(n/N_C)$
$N_C = 2.51x10^{19}cm^{-3}\ (m_n^*/m_o^*)^{3/2} = 3.22x10^{19}cm^{-3}$
$(E_F - E_C)_{left} = (0.0259eV)\ ln(10^{15}cm^{-3}/3.22x10^{19}cm^{-3}) = -0.269eV$
$(E_F - E_C)_{right} = (0.0259eV)\ ln(5x10^{17}cm^{-3}/3.22x10^{19}cm^{-3}) = -0.108eV$



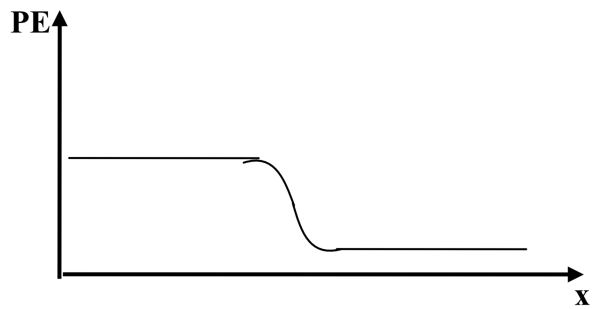
Grading Criteria:
1 point for getting both $E_F - E_C$ correct
1 point for correct band diagram

b) Sketch the electrostatic potential (voltage) vs. position.



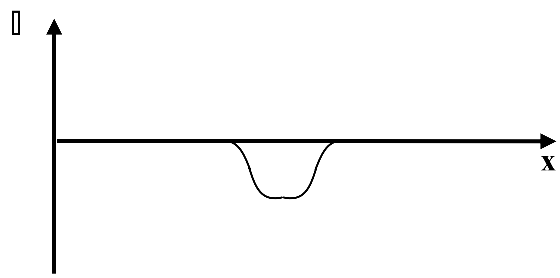
Grading Criteria:
1 point for getting correct diagram

c) Sketch the potential energy vs. position.



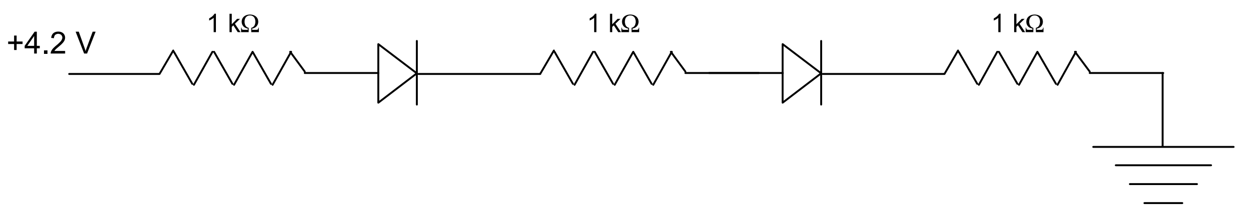
Grading Criteria:
1 point for getting correct diagram

d) Sketch the electric field vs. position.



Grading Criteria:
1 point for getting correct diagram

PROBLEM FOUR: (5 points)

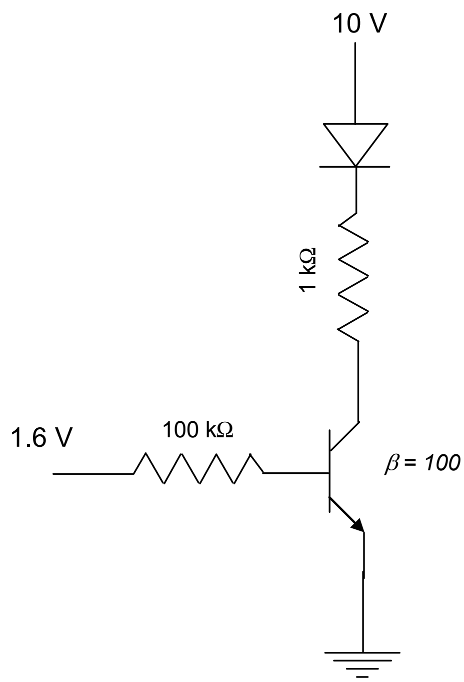


How much current is flowing in this circuit?

V_{diode} = 0.6V
Acceptable Range: 0.5V – 0.7V
I = V/R
= (4.2V – 2(0.6V))/3000Ω
= 1mA
Acceptable Range: 0.8-1.2mA

Grading Criteria:
1 point for correct voltage for diode within given range
4 points for correct answer within given range

PROBLEM FIVE: (5 points)



Find V_C for this circuit.

$V_{diode} = 0.6V$
$V_{BE} = V_B - V_E = 0.6V$
$V_E = 0V$
$V_B = 0.6V$
$I_B = (1.6V - V_B)/100000\Omega = (1.6V - 0.6V)/100000\Omega = 10\mu A$
$I_C = \beta I_B = (100)(10\mu A) = 1mA$
$I_C = (10V - 0.6V - V_C)/1000\Omega$
$(10V - 0.6V - V_C)/1000\Omega = 1mA$
$9.4V - V_C = 1V$
$V_C = 8.4V$
Acceptable Range: 8.2V – 8.6V

Grading Criteria:
1 point for correct V_{diode} within range 0.5V-0.7V
1 point for correct V_{BE} value within range 0.6V-0.7V
1 point for correct collector versus base current equation
2 points for correct answer within range (but only one if you calculate Vc correctly but mislabel it)