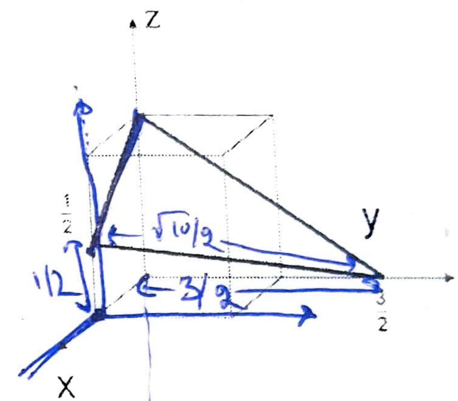
9/15/2017

Date: 16-09-2017 **Quiz-1 (Marks : 10)** **Time: 40 Min**

Q1. Determine the Miller indices of the plane in the figure. **3**



Q2. Draw the diamond structure for silicon and write down the number of atoms in one unit cell of Silicon. **2**

Q3. How do you define direct and indirect semi-conductors? **2**

Q4. Why do we need excess charge carriers and what are the ways to create these excess charge carriers? **2**

Q5. What is the probability of being occupied by an electron of an energy state at the Fermi level? **1**

$\frac{9}{4}+\frac{1}{4}$

$\frac{10}{4}$

$\sqrt{\frac{10}{2}}$

0, 1, $\frac{2}{3}$, 1, 2

0.6, 1.5

Date: 18-11-2017 **Quiz- 2 (Marks : 10)** **Time: 40 Min**

Q1. Draw The Energy Band Diagram in thermal equilibrium for metal semiconductor contacts for $\phi_m < \phi_s$, where type of semiconductor is of n type. [1]

Q2. Write a short-note on Metal-Semicondutor contacts. [2]

Q3. Give the energy band diagram of a MOS system. [1]

Q4. Discuss the surface inversion phenomenon in MOS structure and give its energy band diagram for the same. [3]

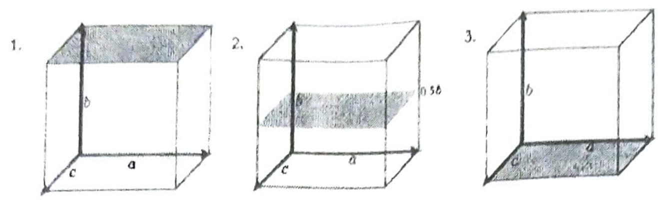
End-Sem Examination
Odd Semester - 2017-18
Semiconductor Devices and Circuits (SEMI)
B.Tech. (ECE) 2nd Year

LNMIIT
The LNM Institute of Information Technology

Time: 3 Hrs **Total Marks: 50**

All Questions are compulsory and Self-Explanatory.

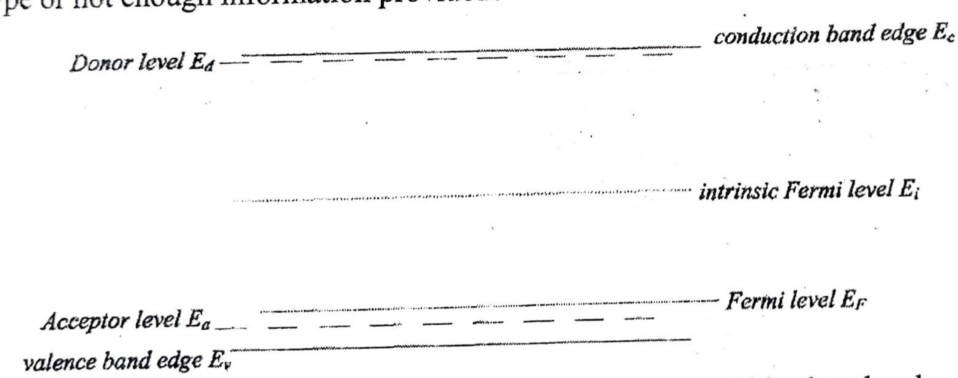
Q1. Discuss all the steps to determine the Miller Indices of a plane. Also, determine the miller indices for the following planes: [2 + 3]



Q2. A Si sample is doped with 10^{17} As atoms/cm^3. What is the equilibrium hole concentration p_0 at 300 K? Where is E_F relative to E_i ? For your calculation you can use $n_i = 1.5 \times 10^{10}$ cm^{-3}, kT = 0.0259 eV. [2]

Q3. Define the Hall Effect in n-type semiconductor. How do we identify the type of a material with the help of the Hall Effect? List down the 4 applications of Hall Effect. [3 +2 +2]

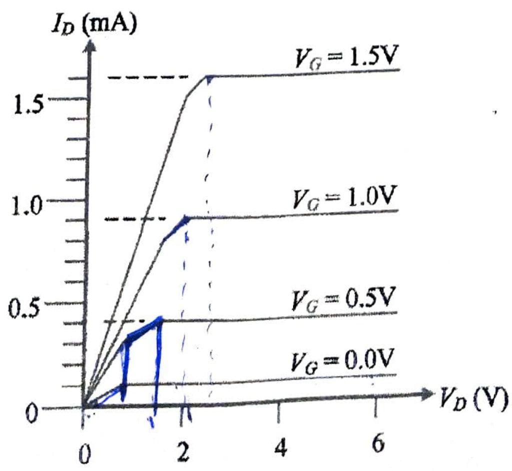
Q4. The equilibrium band diagram for a doped direct gap semiconductor is shown below. Is it n-type, p-type or not enough information provided? [1]



What if any of the following conditions by themselves could lead to the above band diagram? Choose the correct answer from the following: [1]

a) Very high temperature
b) Very high acceptor doping
c) Very low acceptor doping

Q5. Consider the following MOSFET characteristic:



a) Is this an n-channel or p-channel device? [1]
b) Does this appear to be a long-channel or short-channel device? [1]
c) What is the apparent threshold voltage V_T ? [1]
d) Is this a depletion mode or enhancement mode MOSFET? [1]

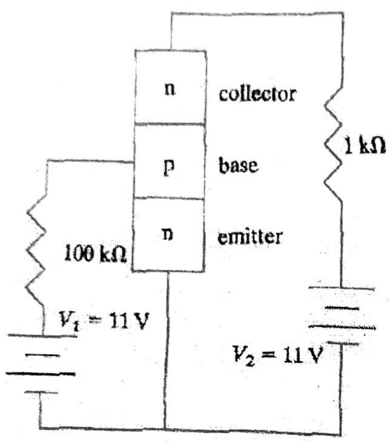
Q6. (a) What is threshold voltage in MOSFET? Derive the *Threshold Voltage* equation for NMOS. Apply the substrate biasing V_{SB} to the derived equation and write down the final equation for the *Threshold Voltage*.

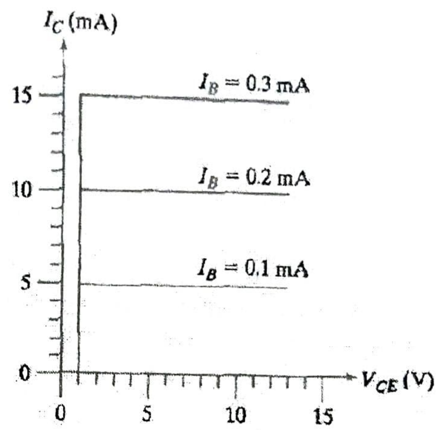
[1 + 3 + 2]

(b) Calculate the threshold voltage V_{T0} at $V_{SB} = 0$, for a polysilicon gate n-channel MOS transistor, with the following parameters: substrate doping density $N_A = 10^{16}$ cm^{-3}, polysilicon gate doping density $N_D = 2 \times 10^{20}$ cm^{-3}, gate oxide thickness $t_{ox} = 50$ nm and oxide-interface fixed charge density N_{ox} 4×10^{10} cm^{-2}. $kT/q = 0.026$ eV, $n_i = 1.45 \times 10^{10}$ cm^{-3}, $\Phi_F(\text{gate}) = 0.55$ V, $\varepsilon_0 = 8.845 \times 10^{-14}$ Fcm^{-1}, $\varepsilon_{si}/\varepsilon_0 = 11.7$, $q = 1.6 \times 10^{-19}$ C

[4]

Q7. Consider the following bipolar junction transistor (BJT) circuit and somewhat idealized transistor characteristics where, in particular, the voltage drop across the forward biased base-emitter junction is assumed to be constant and equal to 1 V for simplicity.





a) What is the (common-emitter) gain β ? [2]
b) Draw the load line on the transistor characteristics. [2]
c) What is the collector-emitter voltage drop in this circuit within half a volt? [2]
d) If voltage V_1 could be changed, what value of V_1 would drive BJT in this circuit to the edge of saturation? [2]

Q8. Discuss the breakdown mechanisms in a lightly doped and heavily doped p-n junction under reverse biased condition.

[2 + 2]

Q9. Write the short note one the followings: [2 + 2 + 2 + 2]

(a) Channel Length Modulation
(b) Drain Induced Barrier Lowering
(c) Excess Charge Carriers in Semiconductors
(d) Continuity Equation

CODE: .... S. No.........2949

The LNM Institute of Information Technology, Jaipur

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Name of the student: Vishakha Ghanwani

Roll No. : 16UEC126

Name of Examination : MID - TERM

Subject : Semiconductor

Day & Date : Tuesday, 26/9/17

No. of Supplementary Sheets Attached: ....

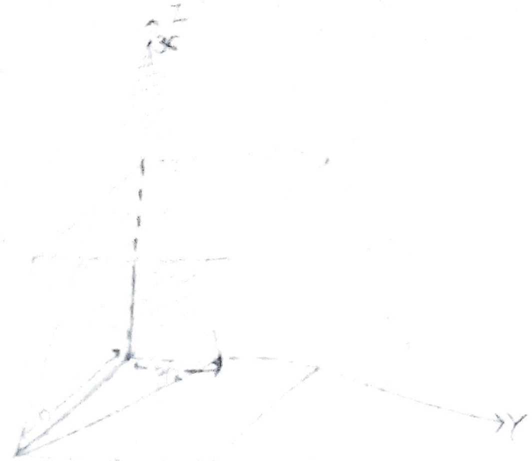
Student's Signature

Invigilator's Signature

Question No.	Marks Obtained
1	4
2	3
3	4
4	3½
5	5
6	3
7	4
8	
9	
10	
Total Marks	26½

30

Miscalculation



2

X - intercept = a
Y - intercept = b/2
Z - intercept = 3c
As it is a unit cell a = 1, b = 1, c = 1
To obtain miller indices Take reciprocal of intercepts

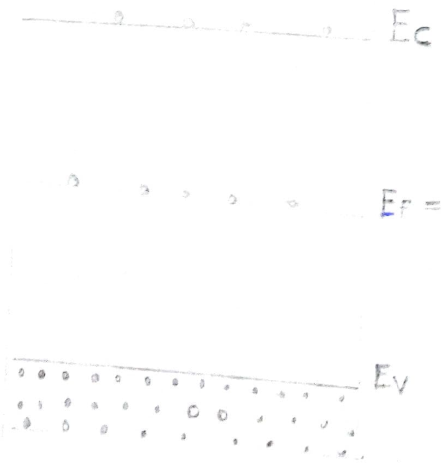
$$\left(1, \frac{1}{1/2}, \frac{1}{3}\right) = \left(1, 2, \frac{1}{3}\right) = (3, 6, 1)$$

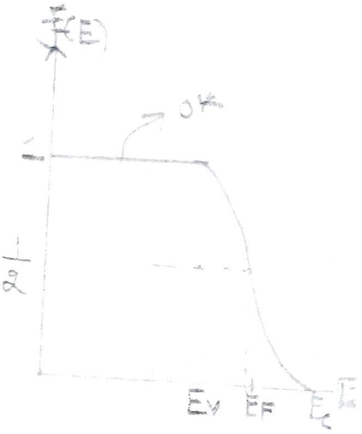
Miller indices of given Plane are (h, k, l) i.e (3, 6, 1)

2

Ans 2

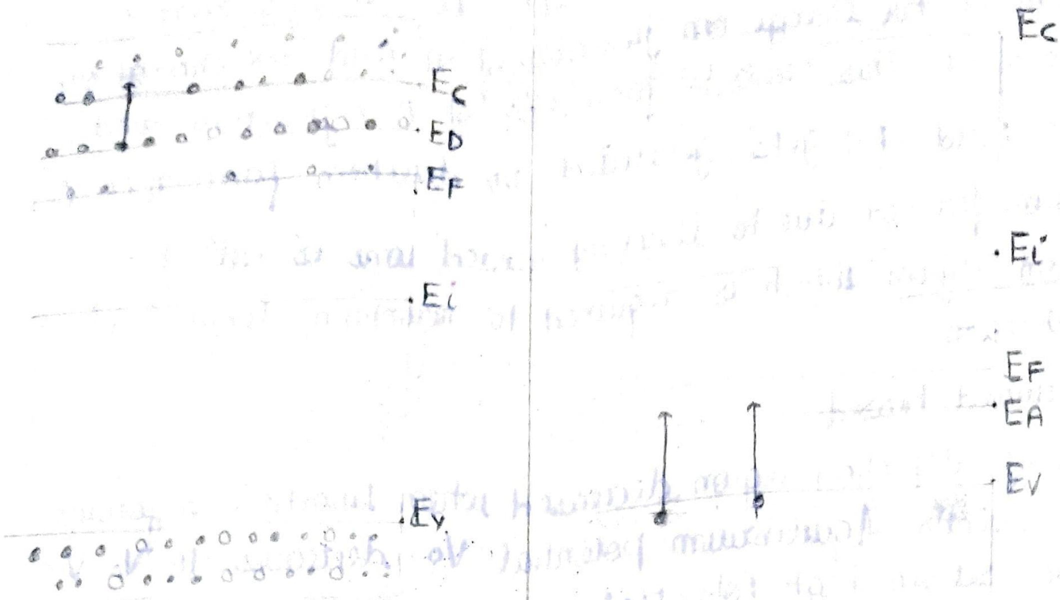
a) Intrinsic Semiconductor



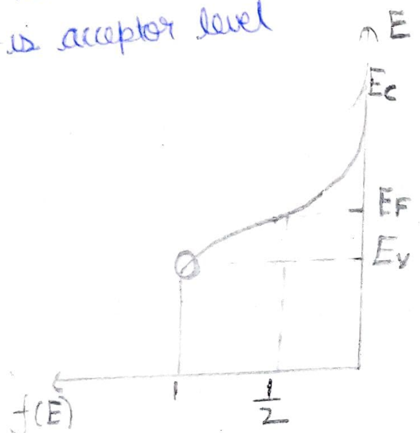


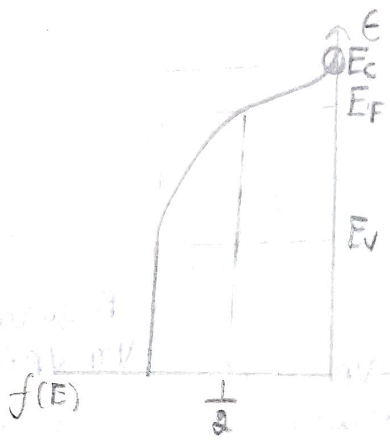
where E_c is Conduction band energy
E_v is valence band energy
E_F Fermi level energy
E_i is intrinsic Fermi level energy

(b) n-type



ED is donor level
EA is acceptor level

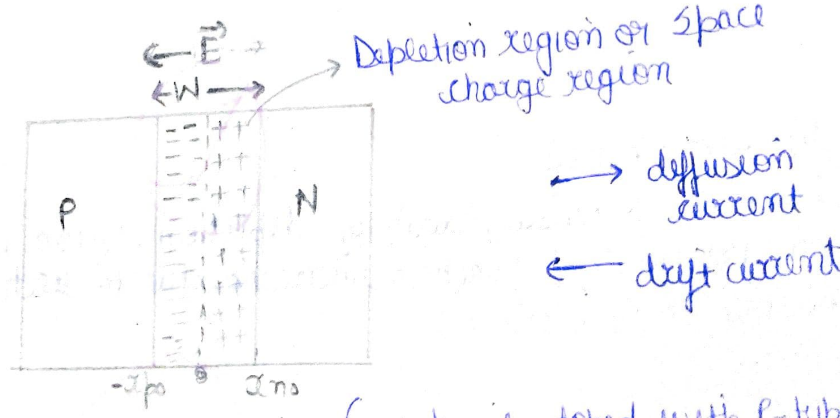




f(E) is fermi Dirac distribution

3

Ques 3



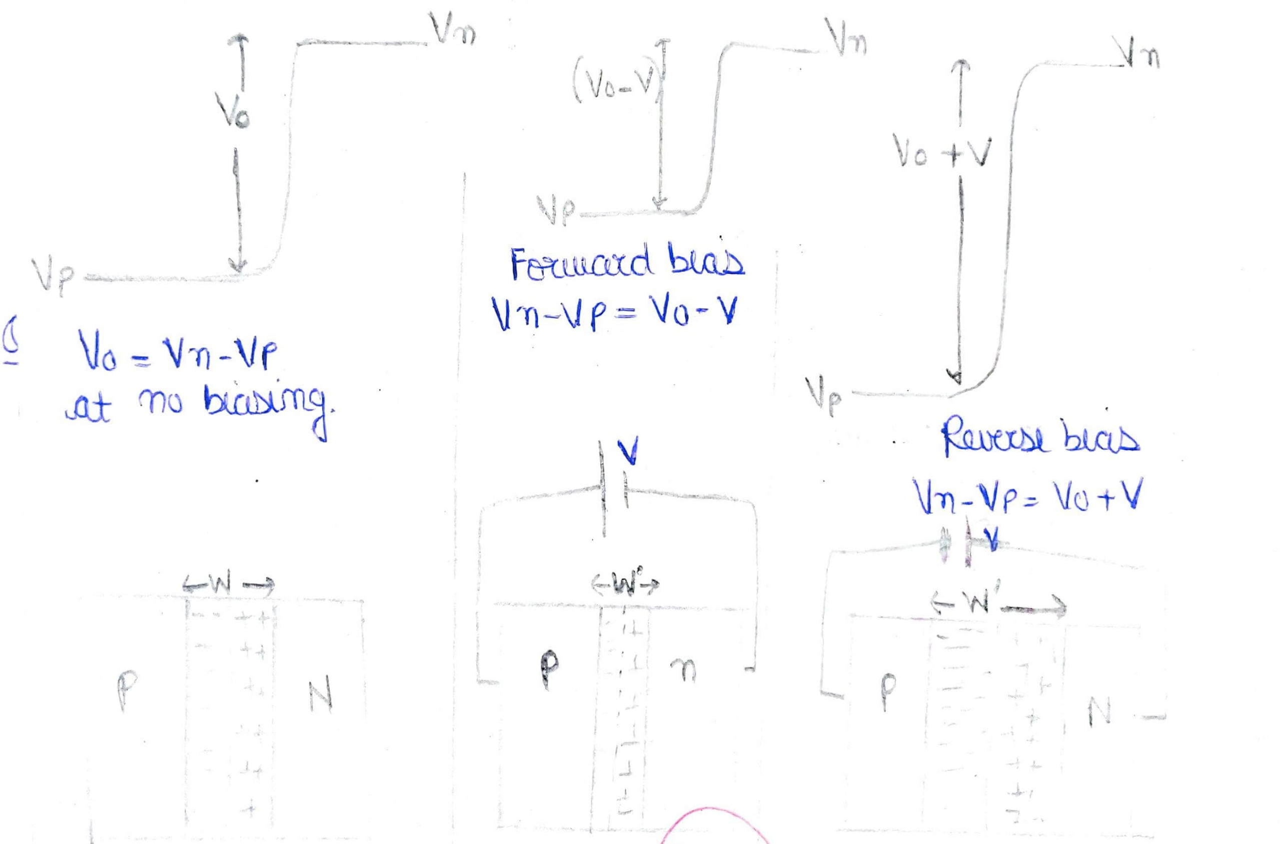
1

A P-N Juction is formed when two materials (one heavily doped with P-type material and other doped with n-type material are brought close together) When P type and n-type materials are brought close then due to concentration gradient holes from P-side move to n-side and e⁻ from n-side move to p-side leading to what is called diffusion process.

holes move from p to n ... behind uncompensated ions N_a^- and when e's move from n to p side they leave behind uncompensated donor ions called N_d^+. Due to this there is formation of +ve charge on junction of n and -ve charge on junction of p. This leads to formation of p-n junction and Electric Field (E) gets generated in direction from n to p. The region formed due to uncompensated ions is called depletion region which is required to maintain fermi level at equilibrium.

(a) Forward biased

Width of depletion region decreased when Junction is forward biased as the equilibrium potential V_o decreases to $V_o - V$ as P is set on high Potential.



(b) Reverse biased

when Reverse biased, width of depletion region increases as Potential of junction increases due to which Electric Field increases

Ques 4 $N_a = 10^{18}\ cm^{-3}$

$N_d = 5\times10^{15}\ cm^{-3}$

diameter of junction $= 10\mu m$

x_{no}, x_{po}, Q_+, E_o, $T = 300K$

$$E_x = -\frac{q N_d x_{no}}{\epsilon} = -\frac{q N_a x_{po}}{\epsilon}$$

$$V_o = \frac{KT}{q}\ln\left(\frac{N_a N_d}{n_i^2}\right) = 0.0259\ln\left(\frac{10^{18}\times 5\times10^{15}}{2.25\times10^{20}}\right)$$

$n_i^2 = 2.25\times10^{20}$

$$V_o = 0.0259\left[\ln\left(\frac{5\times10^{13}\times10^{2}}{225}\right)\right]$$

$$= 0.0259\ln\left(\frac{500}{225}\times10^{13}\right)$$

$$= 0.0259\left[\ln\left(\frac{500}{225}\right) + 13\ln10\right]$$

$$V_o = 0.0259\left[\ln(2.22) + 13\ln10\right] = 0.0259\left[\ln(2.2) + 29.93\right]$$

$$V_o = 0.0259(0.788 + 29.93)$$

$$V_o = 0.0259(30.718)$$

$$V_o = 0.795\ V$$

$$V_o = -\frac{1}{2}E_x W = \frac{1}{2}\frac{q N_d x_{no} W}{\epsilon}$$

$$V_o = \frac{1}{2}\frac{q}{\epsilon}N_d\left(\frac{N_a W}{N_a+N_d}\right)W$$

$$V_o = \left(\frac{1}{2}\frac{q}{\epsilon}\frac{N_a N_d}{N_a+N_d}\right)W^2 = \left(\frac{1}{\cancel{2}}\frac{\overset{0.8}{\cancel{1.6}}\times10^{-19}}{11.8\times8.845\times10^{-14}}\frac{N_a N_d}{(N_a+N_d)}\right)W^2$$

$$= \left(\frac{0.0677\times10^{-5}}{8.845}\right)\frac{N_a N_d}{(N_a+N_d)}W^2$$

$$V_o = \frac{(7.664\times10^{-8})(5\times10^{33})}{(1000+5)10^{15}}W^2$$

$$V_o = \left(\frac{7.664}{1005}\right)\times5\times10^{18}\ W^2$$

$$V_o = (0.0381\times10^{18})W^2$$

$$W = \sqrt{\frac{0.795\times10^{-18}}{0.0381}} = \sqrt{20.866}\times10^{-9}$$

$\boxed{W = 4.56\times10^{-9}}$ cm

$x_{no} = \dfrac{N_a W}{N_a + N_d} = \dfrac{\cancel{10^{18}}\,10^{3} \times 4.56\times10^{-9}}{(1005)\times\cancel{10^{15}}}$

$\boxed{x_{no} = 4.53\times10^{-9}}$ cm

$x_{po} = \dfrac{N_d W}{N_a+N_d} = \dfrac{5\times\cancel{10^{15}} \times 4.56\times10^{-9}}{(1005)\times\cancel{10^{15}}}$

$\boxed{x_{po} = 0.0226\times10^{-9}\ \cancel{m}}$ cm

$Q_+ = A\,q\,N_d\,x_{no}$

$= (\pi r^2)\,q\,N_d\,x_{no}$

$= \pi\left(\frac{10}{2}\,\mu m\right)^2 \times 1.6\times10^{-19} \times 5\times10^{15} \times 4.53\times10^{-9}$

$= \pi\ 25\times10^{-8} \times 1.6\times10^{-19} \times 5 \times 4.53\times10^{6}$

$= 3.14\times 1\ 25 \times 1.6 \times 4.53 \times 10^{-21}$ C

$Q_+ = 2.844\times10^{-18}$ C

3½

<u>Ques 5</u> $T = 300K$

$N_d = 2.73\times10^{16}\ cm^{-3}$

(a) n_o = Concentration of electron in conduction band

2

At equilibrium $n_o \approx N_d$

$\Rightarrow n_o = 2.73\times10^{16}\ cm^{-3}$

$\boxed{n_o p_o = n_i^2}$; n_i is intrinsic carrier concentration

p_o = hole concentration in valence band

$p_o = \dfrac{n_i^2}{n_o} = \dfrac{(1.5\times10^{10})^2}{(2.73\times10^{16})} = \dfrac{2.25\times10^{20}}{2.73\times10^{16}}$

(b) p_o = ~~0.824 cm^{-3}~~ $0.824\times10^{4}\ cm^{-3}$

2

(c) $N_a = 3.5 \times 10^{16}\ cm^{-3}$

now P_o = hole concentration in valence band

$P_o \approx N_a = 3.5 \times 10^{16}\ cm^{-3}$

$n_o = \dfrac{n_i^2}{N_a} = \dfrac{2.25 \times 10^{20}}{3.5 \times 10^{16}}$ ~~$= 0.642 \times 10^{4}\ cm^{-3}$~~

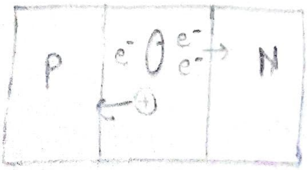
Total hole concentration now is $(8240 + 3.5 \times 10^{16})\ cm^{-3}$

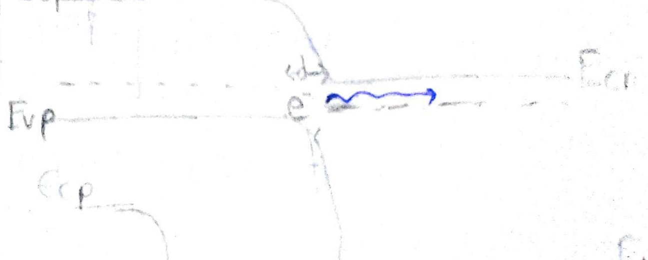
Total electron concentration now is $(2.73 \times 10^{16} + 6420)\ cm^{-3}$

Now hole and electron concentration are almost same but hole concentration is still greater than e⁻ concentration so resulting material is p-type.

Ques 6

Avalanche Breakdown	Zener Breakdown
• This occurs at higher reverse bias voltage.	• This occurs at comparatively lower reverse bias voltage.
• This occurs when material is lightly doped and depletion width is large.	• In this tunneling effect of electron takes place leading to generation of tunneling current.
• In this ionization of host atom takes place when any carrier collides with atom and leads to formation of EHP.	• It occurs when material is highly doped and depletion width is small so that e⁻ can easily go inside tunnel being created.
• If generated carriers have sufficient kinetic energy then they further collide with other atoms and generate more carriers. generated hole is shifted towards P-side and e⁻ is moved towards n-side.	• In this two bands cross each other. empty conduction band of n-side is opposite to filled band i.e valence band of P-side





Sample A

$N_d = 10^{16} cm^{-3}$

$\mu_n = 1000 cm^2/V$

$\mu_p = 300 cm^2/V.s$

$N_c = 2.78 \times 10^{19}$

$KT = 0.0259 eV$

$$V_0 = \frac{KT}{q} \ln \frac{N_a N_d}{n_i^2}$$

$$N_d = N_c e^{(E_c - E_F)/KT}$$

$$\frac{N_d}{N_c} = e^{(E_c - E_F)KT}$$

$$\frac{(E_c - E_F)}{KT} = \ln\left(\frac{N_d}{N_c}\right)$$

$$\frac{+E_F}{0.0259} = \ln\left(\frac{10^{16}}{2.78 \times 10^{19}}\right)$$

$$E_F = 0.0259 \ln\left(\frac{1}{2.78} \times 10^{-3}\right)$$

$$= 0.0259 \left[\ln\left(\frac{100}{278}\right) - 3\ln(10)\right]$$

$$\left(\ln(0.35) - 3(2.303)\right)$$

$$0.0259\,(-1.049 - 6.909)$$

$$0.0259\,(-8.318)$$

$$\boxed{E_F = -0.215 \text{ eV}}$$

2

Sample B

$$N_d = N_c e^{-(E_E - E_F)/KT}$$

$$\ln\left(\frac{N_d}{N_c}\right) = \frac{E_F}{KT}$$

$$E_F = 0.0259 \left[\ln\left(\frac{10^{18}}{2.78 \times 10^{19}}\right)\right]$$

$$0.0259 \left[\ln\left(\frac{100}{278}\right) - 2.303\right]$$

$$0.0259\,(-1.049 - 2.303)$$

$$E_F = 0.0259\,(-3.352)$$

$$\boxed{E_F = -0.08 \text{ eV}}$$

2