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Date
Page 1

EC100 : Assignment 2

(2.1) Q3 (a) Show that the minimum conductivity of a semiconductor sample occurs when $n_o = n_i\sqrt{\frac{\mu_p}{\mu_n}}$

b) what is the expression for minimum conductivity σ_{min}?

c) Calculate σ_{min} for Si at 300K and compare with intrinsic conductivity.

(a) conductivity of a semiconductor is given as,

$$\sigma = (n_o \mu_n + p_o \mu_p) q$$

From mass action law,

$$n_o p_o = n_i^2$$

$$p_o = \frac{n_i^2}{n_o}$$

$$\therefore \sigma = \left(n_o \mu_n + \frac{n_i^2}{n_o}\mu_p\right) q$$

$$\frac{d\sigma}{dn_o} = \left\{\mu_n + \frac{n_i^2}{(-n_o^2)}\mu_p\right\} q$$

$$\frac{d\sigma}{dn_o} = \left(\mu_n - \frac{n_i^2}{n_o^2}\mu_p\right) q$$

To find ~~max~~ minima, we have to put $\frac{d\sigma}{dn_o} = 0$

$$\therefore \mu_n = \frac{n_i^2}{n_o^2}\mu_p$$

Name: Archit Agrawal
Student ID: 202052307

Date
Page 2

$\therefore \quad n_o = n_i \sqrt{\dfrac{\mu_p}{\mu_n}}$

Now, $\quad \dfrac{d^2\sigma}{dn^2} = \dfrac{2 n_i^2 \mu_p q}{n_o^3} \quad$ (always > 0)

$\therefore$ the conductivity will be minimum when
$n_o = n_i \sqrt{\dfrac{\mu_p}{\mu_n}}$

b) $\because \quad n_o p_o = n_i^2$

$\cancel{n_i} \sqrt{\dfrac{\mu_p}{\mu_n}} \, p_o = n_i^{\cancel{2}}$

$p_o = n_i \sqrt{\dfrac{\mu_n}{\mu_p}}$

$\therefore \quad \sigma_{min} = (n_o \mu_n + p_o \mu_p) q$

$= \left(n_i \sqrt{\dfrac{\mu_p}{\mu_n}} \mu_n + n_i \sqrt{\dfrac{\mu_n}{\mu_p}} \mu_p \right) q$

$\sigma_{min} = \left(n_i \sqrt{\mu_p \mu_n} + n_i \sqrt{\mu_p \mu_n} \right) q$

$= 2 n_i \sqrt{\mu_p \mu_n} \, q$

c) For Si at 300 K, $n_i = 1.5 \times 10^{10}$ cm^{-3},
$\mu_p = 500$ $cm^2/V\text{-}s$ and $\mu_n = 1300$ $cm^2/V\text{-}s$

$\therefore \quad \sigma_{min} = 2 \times 1.5 \times 10^{10} (cm^{-3}) \sqrt{500 \times 1300 \; (cm^2/V\text{-}s)} \times q$

$\sigma_{min} = 23.62 \times 10^{10} \times 10^{2} \times 1.6 \times 10^{-19} (\Omega\, cm)^{-1}$

Name: Archit Agrawal
Student ID: 202052307

Date
Page 3

$$\sigma_{min} = 3.779 \times 10^{-6} \ (\Omega \ cm)^{-1}$$

Hence, σ_{min} for Si at 300K is $3.779 \times 10^{-6} \ (\Omega cm)^{-1}$

The intrinsic conductivity of Si at 300K is,

$$\sigma = n_i (\mu_n + \mu_p) q$$
$$= 1.5 \times 10^{10} \times 1800 \times 1.6 \times 10^{-19}$$
$$= 4.32 \times 10^{-6} \ (\Omega cm)^{-1}$$

Hence, intrinsic conductivity of Si at 300K is 1.14 times the minimum conductivity of Si at 300K.

(2.1) Q.11 A conductor material has a free electron density of 10^{24} electrons per m^3. When a voltage is applied, a constant drift velocity of 1.5×10^{-2} m/s is attained by the electrons. If the cross-sectional area of material is 1 cm^2, calculate the magnitude of current.

density of free electrons $(n) = 10^{24}$ electrons/m^3
drift velocity $(v) = 1.5 \times 10^{-2}$ m/s
cross-sectional area $(A) = 1 \ cm^2 = 10^{-4} \ m^2$

current density $J = nqv$
$$J = 10^{24} \times 1.6 \times 10^{-19} \times 1.5 \times 10^{-2}$$
$$J = 2.4 \times 10^{3} \ A/m^2$$

$\therefore$ current $i = JA$
$$i = 2.4 \times 10^{3} \times 10^{-4} \ A$$
$$i = 0.24 \ A$$

Therefore, the current in the conductor is 0.24A.

Name : Archit Agrawal
Student ID : 202052307

2.1 Q12 A copper wire of 2mm diameter with conductivity of $5.8 \times 10^{7}\ S m^{-1}$ and electron mobility of $0.0032\ m^2/Vs$ is subjected to an electric field of $20\ mV\ m^{-1}$. Find i) charge density ii) current density iii) current flowing in wire iv) the electron drift velocity.

radius of copper wire $= 1\,mm = 10^{-3}\,m$
cross-section area$(A) = \pi \times 10^{-6}\ m^2$
conductivity of copper wire $(\sigma) = 5.8 \times 10^{7}\ Sm^{-1}$
electron mobility $(\mu) = 0.0032\ m^2/Vs$
electric field $(E) = 20 \times 10^{-3}\ V m^{-1}$

i) Since $\sigma = nq\mu$ and charge density $K = nq$

$\therefore \sigma = K\mu$

$\therefore K = \frac{\sigma}{\mu} = \frac{5.8 \times 10^{7}}{0.0032} = 1.8125 \times 10^{10}\ C m^{-3}$

(ii) current density $J = \sigma E$

$J = 5.8 \times 10^{7} \times 20 \times 10^{-3}$
$= 1.16 \times 10^{6}\ A m^{-2}$

(iii) current flowing in wire $(i) = JA$
$= 1.16 \times 10^{6} \times \pi \times 10^{-6}$
$= 3.6424\ A$

(iv) current density $(J) = nev = Kv$

$\therefore$ drift velocity $(v) = \frac{J}{K} = \frac{1.16 \times 10^{6}}{1.8125 \times 10^{10}}$

$v = 6.4 \times 10^{-5}\ m/sec$

Name : Archit Agrawal
Student ID : 202052307

2.1 (Q.21) Find the concentration of holes and electrons in an N-type semiconductor (silicon) at 300K if the conductivity is $0.1\ \Omega^{-1}\text{cm}^{-1}$. Given that n_i at 300K for silicon is $1.5 \times 10^{10}/\text{cm}^3$ and μ_e at 300K for Si is $1300\ \text{cm}^2 V^{-1} s^{-1}$.

In n-type semiconductor, conductivity is given by

$$\sigma = n \mu_n q$$

where n is conc. of electrons and μ_n is mobility of electrons

$$\therefore n = \frac{\sigma}{q \mu_n}$$

$$\therefore n = \frac{0.1\ \Omega^{-1}\ \text{cm}^{-1}}{1.6 \times 10^{-19} \times 1300\ \text{cm}^2 V^{-1} s^{-1}}$$

$$\therefore n = 4.8 \times 10^{-5} \times 10^{19}\ \text{cm}^{-3}$$

$$n = 4.8 \times 10^{14}\ \text{cm}^{-3}$$

$\therefore$ concentration of electrons in the specimen is $4.8 \times 10^{14}\ \text{cm}^{-3}$ at 300K.

from mass action law,

$$np = n_i^2$$

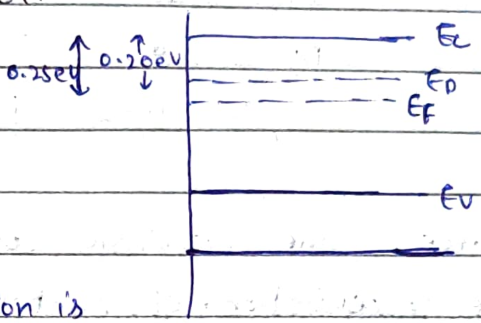
$$\therefore p = \frac{n_i^2}{n} = \frac{(1.5 \times 10^{10})^2}{4.8 \times 10^{14}}$$

$$p = 4.68 \times 10^{5}\ \text{cm}^{-3}$$

$\therefore$ concentration of holes in the specimen is $4.68 \times 10^{5}\ \text{cm}^{-3}$ at 300K.

Name: Archit Agrawal
Student ID: 2020 52307

(2.1) Q.1) An unknown semiconductor has $E_g = 1.1\,eV$ and $N_c = N_v$. It is doped with $10^{15}\ cm^{-3}$ donors, where the donor level is 0.2 eV below E_c. Given that E_F is 0.25 eV below E_c, calculate n_i and the concentration of electrons and holes in the semiconductor at 300K.



$E_g = E_c - E_v = 1.1\,eV$

$E_c - E_F = 0.25\,eV$

$N_c = N_v$

Since, donor concentration is $10^{15}\ cm^{-3}$,

$\therefore \quad n = 10^{15}\ cm^{-3}$

Since $\quad n = N_c\, e^{-(E_c - E_F)/KT}$

$$N_c = n\, e^{(E_c - E_F)/KT}$$

$$N_v = N_c = 10^{15}\, e^{0.25/0.0259}$$

$$= 15560 \times 10^{15}\ cm^{-3}$$

$$= 1.556 \times 10^{19}\ cm^{-3}$$

and, $\quad p = N_v\, e^{-(E_F - E_v)/KT}$ —— (11)

Since, $\quad E_c - E_v = E_a$

$$(E_c - E_F) - (E_v - E_F) = E_a$$

$$-(E_v - E_F) = E_a - (E_c - E_F)$$

$$E_F - E_v = 1.1 - 0.25$$

$$= 0.85\ eV$$

Putting $E_F - E_v = 0.85$ in (11),

$$p = 1.556 \times 10^{19}\ e^{-0.85/0.0259}\ cm^{-3}$$

$$p = 1.556 \times 10^{19} \times 5.506 \times 10^{-15}$$

Name : Archit Agrawal
Student ID : 202052307

$p = 8.69 \times 10^{4}$ cm^{-3}

According to Mass Action Law,

$np = n_i^2$

$n_i^2 = 10^{15} \times 8.69 \times 10^{4}$

$n_i^2 = 86.9 \times 10^{18}$ cm^{-6}

$n_i = 9.32 \times 10^{9}$ cm^{-3}

Hence, the intrinsic concentration $n_i = 9.32 \times 10^9$ cm^{-3}, the concentration of electrons $n = 10^{15}$ cm^{-3} and concentration of holes $p = 8.69 \times 10^4$ cm^{-3}.

2.1 Q.9) The energy band gap of germanium is 0.72 eV at 300K. Determine the fraction of the total number of electrons in conduction band at 300K. Boltzmann constant is 8.61×10^{-5} eV/K.

$E_g = 0.72$ eV at 300 K

$\therefore$ $n = N_c e^{-(E_c - E_f)/KT}$ — (1)

$E_c - E_f = \frac{E_g}{2} = 0.36$ eV

$\therefore$ $\frac{n}{N_c} = e^{-0.36/300 \times 8.61 \times 10^{-5}}$

$\frac{n}{N_c}$ is fraction of total electrons in conduction band at 300K.

$\frac{n}{N_c} = 8.85 \times 10^{-7}$

Hence, fraction of total number of electrons in

Name: Archit Agrawal
Student ID: 202052307

Date
Page 8

conduction band is 8.85×10^{-7}.

(2.1) Q.17 In a p-type semiconductor, the Fermi level is 0.27 eV above valence band at a room temperature of 300 K. Find the new position of fermi level at temperature of 400 K.

$$\because \quad p = N_v e^{-(E_F - E_V)/KT}$$

$$\therefore \quad KT \ln\left(\frac{p}{N_v}\right) = -(E_F - E_V)$$

$$E_F - E_V = -KT \ln\left(\frac{p}{N_v}\right)$$

when $T = 300K$, $E_F - E_V = 0.27\,eV$

$$0.27 = -K(300) \ln\left(\frac{p}{N_v}\right) \quad \text{---(I)}$$

when $T = 400\,K$, let $E_F - E_V = a\,eV$

$$a = -K(400) \ln\left(\frac{p}{N_v}\right) \quad \text{---(II)}$$

Dividing (I) by (II),

$$\frac{0.27}{a} = \frac{300}{400}$$

$$a = 0.36\,eV$$

Hence, the new position of Fermi level at $T = 400K$ is 0.36 eV above valence band.

Name : Archit Agrawal
Student ID : 202052307

Q.1 (18) In a n type semiconductor, the Fermi level lies 0.3 eV below the conduction band. Find the new position of Fermi level if the conc. of donor atoms is made 5 times. Assume $KT = 0.026 eV$.

$$\because \quad n = N_c e^{-(E_c - E_F)/KT}$$

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

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

when concentration of e^- is n, $E_c - E_F = 0.3 eV$

$$0.3 = -KT \ln\left(\frac{n}{N_c}\right) \quad \text{— (I)}$$

when concentration of e^- is 5n, let $E_c - E_F = a$

$$a = -KT \ln\left(\frac{5n}{N_c}\right) \quad \text{— (II)}$$

Subtracting (I) from (II),

$$a - 0.3 = KT \ln\left(\frac{n}{N_c}\right) - KT \ln\left(\frac{5n}{N_c}\right)$$

$$a = 0.3 + \cancel{KT \ln\left(\frac{n}{N_c}\right)} - \cancel{KT \ln\left(\frac{n}{N_c}\right)} - KT \ln 5$$

$$a = 0.3 - 0.026 \times 1.609$$

$$a = 0.3 - 0.042$$

$$a = 0.258 eV$$

Hence, the new position of Fermi level is 0.258 eV below the conduction band.

Name: Archit Agrawal
Student ID: 202052307

(2.1) Q 24 what is the donor concentration in a sample of N+ type germanium having a resistivity of 0.1 Ωm at 300K ?

The sample has a resistivity is 0.1 Ωm

∴ conductivity = $10\ (\Omega m)^{-1}$

for a n-type semiconductor, conductivity is given by

$$\sigma = n \mu_n q$$

μ_n for Ge at 300K = $3800\ cm^2 V^{-1} s^{-1} = 0.38\ m^2 V^{-1} s^{-1}$

$$\therefore\ n = \frac{\sigma}{\mu_n q}$$

$$n = \frac{10}{0.38 \times 1.6 \times 10^{-19}}$$

$$n = 1.645 \times 10^{20}\ /m^3$$

Since in n-type semiconductor, donor concentration is almost equal to concentration of electrons

∴ donor concentration in given sample is $1.645 \times 10^{20}\ /m^3$.

Name: Archit Agrawal
Student ID: 202052307

Q.1) Q.15 Find the conductivity of intrinsic germanium at 300 K. If donor type impurity is added to extent of 1 impurity atom in 10^7 germanium atoms, find its conductivity. Given that n_i at 300 K is $2.5 \times 10^{13} /cm^3$ and μ_n and μ_p in germanium are 3800 and 1800 $cm^2/V\text{-}s$ respectively.

Conductivity of intrinsic germanium (σ_i) is given by,

$$\sigma_i = n_i (\mu_n + \mu_p) q$$

$$= 2.5 \times 10^{13} \ cm^{-3} \ (3800 + 1800) \ cm^2 V^{-1} s^{-1} \times 1.6 \times 10^{-19} C$$

$$= 22400 \times 10^{-6} \ (\Omega \ cm)^{-1}$$

$$= 2.24 \times 10^{-2} \ (\Omega \ cm)^{-1}$$

Since, germanium contains 4.4×10^{22} atoms/cm^3.

$\therefore$ donor impurity concentration $= \dfrac{4.4 \times 10^{22}}{10^7}$ atoms/cm^3

$= 4.4 \times 10^{15}$ atoms/cm^3.

Adding donor impurity makes it a n-type semiconductor, and in n-type semiconductor, conductivity is given by

$$\sigma_n = N_D \mu_n q$$

$$\sigma_n = 4.4 \times 10^{15} \ cm^{-3} \times 3800 \ cm^2 V^{-1} s^{-1} \times 1.6 \times 10^{-19} C$$

$$\sigma_n = 26752 \times 10^{-4} = 2.6752 \ (\Omega cm)^{-1}$$

Hence, intrinsic conductivity of Ge at 300K is

Name: Archit Agrawal
Student ID: 202052307

$2.24 \times 10^{-2}\ (\Omega cm)^{-1}$ and conductivity at 300K when donor impurity is added as 1 atom in 10^7 Ge atoms is $2.6752\ (\Omega cm)^{-1}$.

2.2 Q.3. Find the resistivity of (a) intrinsic silicon b) p type silicon doped with $N_A = 10^{16}/cm^3$. Use $n_i = 1.5 \times 10^{10}\ cm^{-3}$, and assume for intrinsic silicon $\mu_n = 1350\ cm^2/V\text{-}s$ and $\mu_p = 480\ cm^2/V\text{-}s$, and for doped silicon $\mu_n = 1110\ cm^2/V\text{-}s$ and $\mu_p = 400\ cm^2/V\text{-}s$.

(a) conductivity of intrinsic semiconductor is given as

$$\sigma_i = n_i(\mu_n + \mu_p)\,q$$

$$= 1.5 \times 10^{10} \times (1350 + 480) \times 1.6 \times 10^{-19}\ (\Omega cm)^{-1}$$

$$= 4392 \times 10^{-9}\ (\Omega^{-1} cm^{-1})$$

$$= 4.39 \times 10^{-6}\ (\Omega cm)^{-1}$$

$\therefore$ resistivity ~~of~~ intrinsic silicon is,

$$\rho_i = \frac{1}{\sigma_i} = \frac{1}{4.39 \times 10^{-6}}$$

$$\rho_i = 2.27 \times 10^5\ \Omega cm$$

b) p-type silicon doped with $N_A = 10^{16}/cm^3$.

In p type semiconductor conductivity is given by

$$\sigma_p = p\,\mu_p\,q$$

In p type semiconductor $p \simeq N_A$

Name: Archit Agrawal
Student ID: 202052307

$\therefore \quad \sigma_p = N_A \mu_p q$

$\sigma_p = 10^{16} \times 400 \times 1.6 \times 10^{-19}$
$= 0.64 \ (\Omega cm)^{-1}$

$\therefore$ resistivity $\rho_p = \frac{1}{\sigma_p} = \frac{1}{0.64}$

$= 1.5625 \ \Omega cm$

Hence, resistivity of silicon semiconductor when doped with acceptor impurity $N_a = 10^{16}/cm^3$ is ~~1.5625 Ωcm~~. 1.5625 Ωcm.

(2.2) Q.4). Consider a bar of silicon in which hole concentration profile described by

$$p(x) = p_o e^{-x/L_T}$$

is established. Find the hole current density at $x = 0$, Let $p_o = 10^{16} cm^{-3}$ and $L_p = 1 \ \mu m$. If cross-sectional area of bar is $100 \ \mu m^2$, find current I_p.

The hole current density is given by

$$J_p = -q D_p e^{-x/L_T} \quad (1)$$

$\therefore \quad p(x) = p_o e^{-x/L_T}$

$\therefore \quad \frac{d p(x)}{dx} = -\frac{p_o}{L_T} e^{-x/L_T}$

$p_o = 10^{16} cm^{-3}, \quad L_T = 1 \ \mu m$

$$\therefore \left.\frac{d(P_x)}{dx}\right|_{at\,x=0} = \frac{-P_0}{L_T}$$

$$= -\frac{10^{16}\ cm^{-3}}{10^{-4}\ cm}$$

$$= -10^{20}\ cm^{-4}.$$

$\because$ D_p for silicon is $13\ cm^2 s^{-1}$.

$$\therefore J_p = -1.6\times10^{-19} \times 13\ cm^2 s^{-1} \times -10^{20}\ cm^{-4}$$

$$= 208\ A\,cm^{-2}$$

$$= 208 \times 10^{4}\ A\,m^{-2}$$

Hence, hole current density is $2.08\times10^{6}\ A\,m^{-2}$.

cross sectional area $(A) = 100\times10^{-6}\times10^{-6}\ m^2$

$$= 10^{-10}\ m^2$$

$\therefore$ diffusion current due to hole $(I_p) = JA$

$$= 2.08\times10^{6}\times10^{-10}$$

$$= 2.08\times10^{-4}\ A$$

$$= 208\ \mu A$$

Hence, hole diffusion current at $x = 0$ is $208\ \mu A$.

(2.2) Q.9. Use the Einstein relationship to find D_n and D_p for intrinsic silicon using $\mu_n = 1350\ cm^2 V^{-1} s^{-1}$ and $\mu_p = 480\ cm^2 V^{-1} s^{-1}$, at 300 K.

Name: Archit Agrawal
Student ID: 202052307

Date
Page 15

The Einstein relationship is,

$$\frac{D_p}{\mu_p} = \frac{D_n}{\mu_n} = \frac{T}{11600}$$

$$\therefore \frac{D_p}{\mu_p} = \frac{T}{11600}$$

$$\therefore D_p = \frac{\mu_p T}{11600} = \frac{480\ cm^2\ V^{-1} s^{-1} \times 300}{11600}$$

$$= 12.41\ cm^2\ s^{-1}$$

and since, $\frac{D_n}{\mu_n} = \frac{D_p}{\mu_p}$

$$D_n = \frac{\mu_n D_p}{\mu_p}$$

$$D_n = \frac{1350 \times 12.41}{480}$$

$$D_n = 34.90\ cm^2\ s^{-1}.$$

Hence, $D_n = 34.9\ cm^2 s^{-1}$ and $D_p = 12.41\ cm^2 s^{-1}$.

(2.1) Q.30 Determine the built-in potential of a silicon p-n junction at 300K with doping density of $N_A = 10^{16}\ cm^{-3}$ and $N_D = 10^{15}\ cm^{-3}$ for intrinsic concentration of $1.5 \times 10^{10}\ cm^{-3}$.

Given $N_A = 10^{16}\ cm^{-3}$, $N_D = 10^{15}\ cm^{-3}$ and
$n_i = 1.5 \times 10^{10}\ cm^{-3}$.

Name: Archit Agrawal
Student ID: 202052307

$$V_0 = V_T \ln\left(\frac{N_A \cdot N_D}{n_i^2}\right)$$

where V_0 is built in potential of p-n junction

and $V_T = \frac{kT}{q} = \frac{T}{11600}$ Volts

$$\therefore V_0 = \frac{300}{11600} \ln\left(\frac{10^{16} \times 10^{15}}{1.5 \times 1.5 \times 10^{20}}\right)$$

$$V_0 = \frac{3}{116} \ln\left(\frac{\cancel{10000}^{40} \times 10^{10}}{\cancel{2.25}_{9}}\right)$$

$$V_0 = \frac{2.303 \times 3}{116}\left\{\log\left(\frac{40}{9}\right) + \log\left(10^{10}\right)\right\}$$

$$V_0 = \frac{2.303 \times 3}{116} \times \left\{0.648 + 10\right\}$$

$$= \frac{2.303 \times 3 \times 10.648}{116}$$

$$V_0 = 0.635 \text{ V}$$

Hence, built in potential of p-n junction is 0.635 V.

(2.1) Q.19) A germanium diode has each of the acceptor and donor impurities of concentration 9.5×10^{14} cm^{-3}. Assume $n_i = 2.5 \times 10^{13}$ cm^{-3}. At room temperature of 300K, calculate the height of potential barrier under open circuited conditions. Boltzmann constant $k = 1.38 \times 10^{-23}$ J/K.

Name : Archit Agrawal
Student ID : 202052307

Given, $N_A = N_D = 9.5 \times 10^{14}\ cm^{-3}$

and $n_i = 2.5 \times 10^{13}\ cm^{-3}$ and $T = 300K$

$$V_0 = V_T \ln\left(\frac{N_A \cdot N_D}{n_i^2}\right)$$

V_0 is height of potential barrier in open-circuited condition.

and, $$V_T = \frac{KT}{q} = \frac{1.38 \times 10^{-23} \times T}{1.6 \times 10^{-19}} = \frac{T}{11600}\ \text{Volts}$$

$$\therefore V_0 = \frac{T}{11600} \ln\left(\frac{N_A \cdot N_D}{n_i^2}\right)$$

$$V_0 = \frac{300}{11600} \ln\left(\frac{9.5 \times 10^{\cancel{14}} \times 9.5 \times 10^{\cancel{14}}}{2.5 \times \cancel{10^{13}} \times 2.5 \times \cancel{10^{13}}}\right)$$

$$V_0 = \frac{3}{116} \ln\left(\frac{19 \times 19 \times 100}{5 \times 5}\right)$$

$$V_0 = \frac{3}{116} \ln\left(\frac{36100}{25}\right)$$

$$V_0 = \frac{3}{116} \ln(1444)$$

$$V_0 = \frac{3 \times 7.275}{116} = 0.188\ \text{volts}$$

Hence, the height of potential barrier in open-circuited condition is 0.188 V.

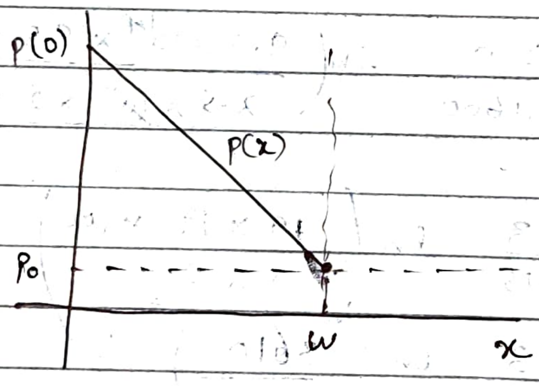
Name : Archit Agrawal
Student ID : 202052307

(2.2) Q.36 The hole concentration in a semiconductor specimen is shown.

a) Find an expression for J_p and sketch the hole current density $J_p(x)$ for the case in which there is no externally applied electric field.

b) Find an expression and sketch the built-in electric field that must exist if there is to be no net hole current associated with the distribution shown.

c) Find the value of potential between the points $x=0$ and $x=W$ if $p(0)/p_0 = 10^3$.



a) from the graph; p(x) is related to x as

$$p(x) = \left(\frac{p_0 - p(0)}{W - 0}\right) x + p(0)$$

$$p(x) = \frac{\{p_0 - p(0)\} x + W p(0)}{W}$$

$$\therefore \frac{dp(x)}{dx} = \frac{p_0 - p(0)}{W}$$

Name : Archit Agrawal
Student ID : 202052307

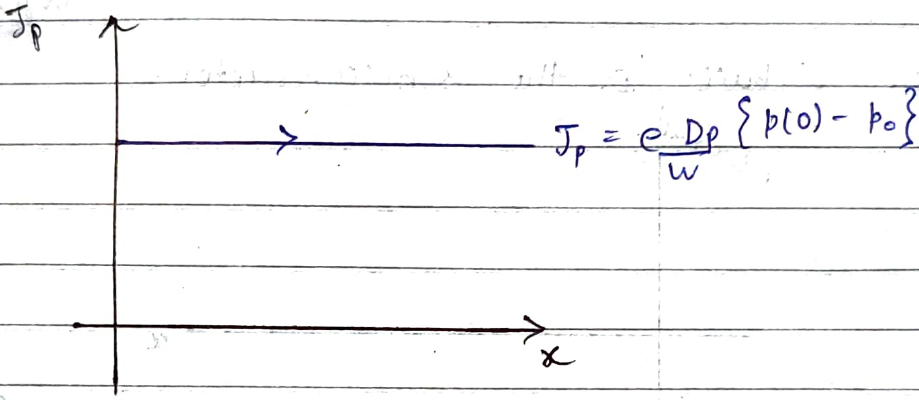
∵ diffusion current density due to holes is given by

$$J_p = -q D_p \frac{d p(x)}{dx}$$

$$\therefore \quad J_p = -e D_p \left\{ \frac{p_0 - p(0)}{W} \right\}$$

$$J_p = \frac{e D_p}{W} \{ p(0) - p_0 \}$$

Hence, diffusion current density is constant.



b) If no net hole current is associated, there must ~~be~~ exist a drift hole current.

Net current density due to hole is given by $J_{p_{net}}$

$$\cancel{J_{p_{net}} = p e \mu_p E +}$$

$$J_{p_{net}} = \text{drift current density} + \text{diffusion current density}$$

$$J_{p_{net}} = p_0 e \mu_p E + \frac{e D_p}{W} \{ p(0) - p_0 \}$$

net hole current density = 0, i.e. $J_{p_{net}} = 0$

Here, p_0 is conc. of holes and E is electric field built-in the semiconductor.

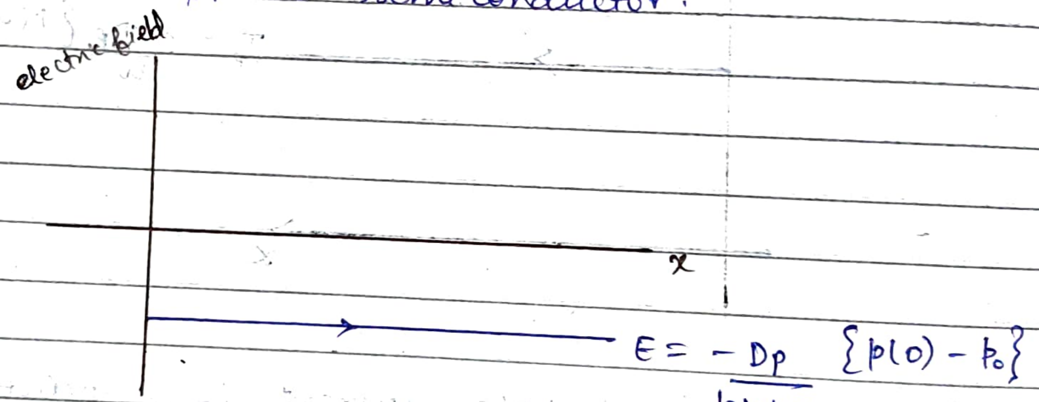
Name: Archit Agrawal
Student ID: 202052307

$$\therefore p_0 e \mu_p E = + \frac{e D_p}{W} \{p(0) - p_0\}$$

$$\therefore E = - \frac{e D_p}{W p_0 e \mu_p} \{p(0) - p_0\}$$

$$\therefore E = - \frac{D_p}{W p_0 \mu_p} \{p(0) - p_0\}$$

Hence, a constant electric field $E = \frac{-D_p \{p(0) - p_0\}}{W p_0 \mu_p}$ will be inbuilt in the semiconductor.



(c) $\because E = -\frac{dV}{dx}$

$$-\frac{dV}{dx} = \frac{-D_p}{W p_0 \mu_p} \{p(0) - p_0\}$$

$$\int_0^V dV = \int_0^W \frac{D_p}{p_0 W \mu_p} \{p(0) - p_0\} \, dx$$

$$V = \frac{D_p \{p(0) - p_0\}}{p_0 W \mu_p} (x)\Big|_0^W$$

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$$V = \frac{D_p \{p(0) - p_0\} \cancel{W}}{p_0 \cancel{W} \mu_p}$$

$$V = \frac{D_p}{\mu_p} \left\{ \frac{p(0)}{p_0} - 1 \right\}$$

For semiconductor $\frac{D_p}{\mu_p} = V_T$. Since T is not given, assume it to be room temperature.

$$\therefore V_T = \frac{T}{11600} \text{ Volts} = \frac{300}{11600} \text{ Volts}$$

$$\therefore V = \frac{3}{116} \{10^3 - 1\} \qquad \left(\text{given } \frac{p(0)}{p_0} = 10^3 \right)$$

$$V = \frac{3 \times 999}{116}$$

$$V = 25.83 \text{ V}$$

Hence value of potential between $x = 0$ and $x = W$ is 25.83 V.