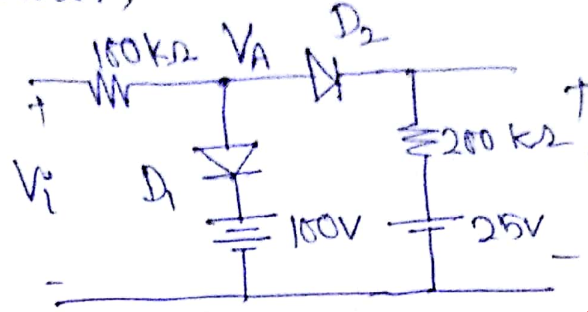
TEST 5:-

ANALOG & MATERIAL SCIENCE

EDC1 & ADVANCE ELECTRONICS1+

DIGITAL & ANALOG COMMUNICATION2

1 (a) Given network,



Given circuit is a clipper circuit, As Both the diode are ideal, these will turn on for different value of input volt.

For Input voltage	D_1	D_2	~~Vout~~ V_o
$0 < V_i < 25\,V$	OFF	OFF	25V
$25 \leq V_i < V'$	OFF	ON	$V_o = \dfrac{25 \times 100 + V_i\, 200}{200 + 100}$

$$V_o = \frac{2}{3} V_i + \cancel{12.5}\ \frac{25}{3}$$

At $V_i = V'$, $V_o = 100\,V$

$$100 = \frac{2}{3} V' + \cancel{12.5}\ \frac{25}{3}$$

$$\rightarrow \quad V' = 137.5\,V$$

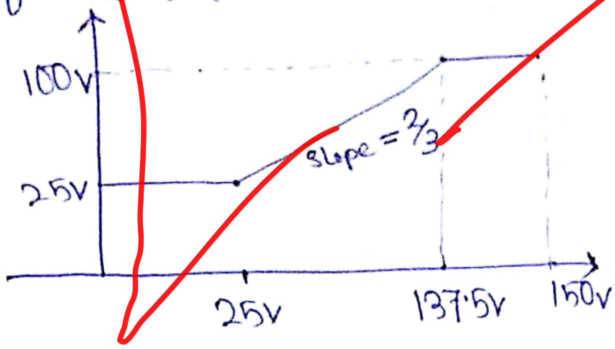
Therefore, for, $25 \leq V_i < 137.5\,V$, D_1 will be in cut OFF condition and D_2 will conduct (ON.).

And $V_o = \frac{2}{3} V_i + \frac{25}{3}\ V.$

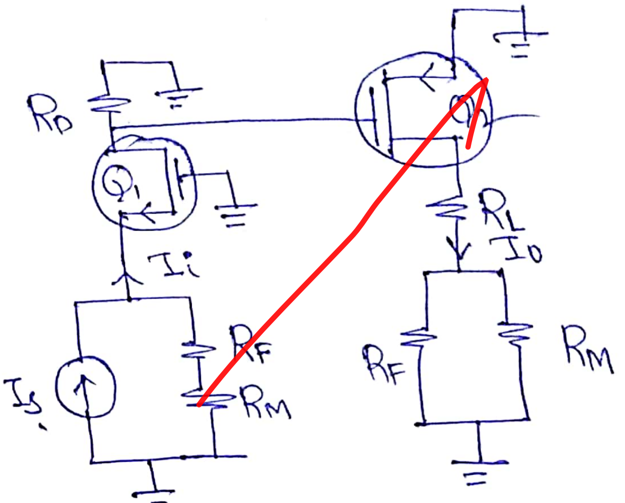
For $V_i \geq 137.5$ Both the diode will conduct i.e. will be in ON state.

And $V_o = 100\,V.$

So, transfer characteristics of given circuit, for $0 \le V_i \le 150$ V

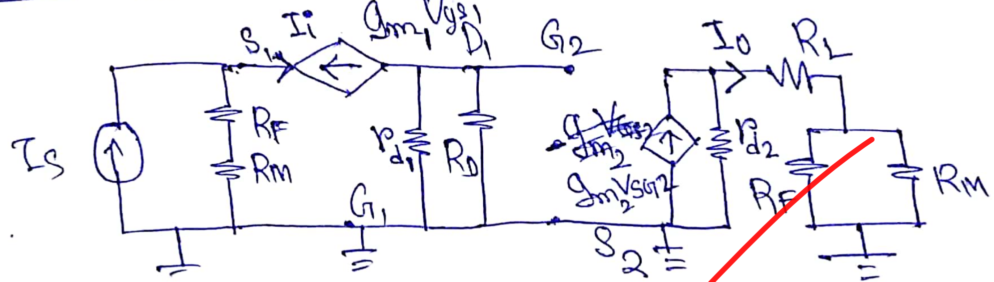


1 (b) AC equivalent of the given network, without feedback



Small Signal equivalent.

(1)



~~Gen~~ Let assume $\lambda = 0$, Hence, $r_{d_1} \to \infty$

$r_{d_2} \to \infty$.

~~By ohm's law at node D, S1~~

$\cancel{V_{GS_2}} \cancel{=}$

By KCL, at node S_1

$$I_i = -g_{m_1} V_{GS_1} \quad \text{———} \quad (1)$$

And,

$$\cancel{V_{GS_2}} = V_{SG_2} = -R_D I_i \quad \text{———} \quad (2)$$

And output current

$$I_0 = g_{m_2} V_{SG_2} \quad \text{——— (3)}$$

From eqn (2) and eqn (3) we, get.

$$I_0 = - g_{m_2} R_D I_i$$

$$\Rightarrow \boxed{A = \frac{I_0}{I_i} = - g_{m_2} R_D} \quad \text{——— (4)}$$

(ii) Feedback factor,

~~$V_{R_M} =$~~

By using Current division rule,

$$I_f = - \frac{R_M}{R_F + R_M} I_0$$

$$\Rightarrow \boxed{\beta = \frac{I_f}{I_0} = - \frac{R_M}{R_F + R_M}}$$

(iii) Desensitivity factor,

$$D = 1 + A\beta = \left(1 + \frac{g_{m_2} R_D R_M}{R_F + R_M}\right)$$

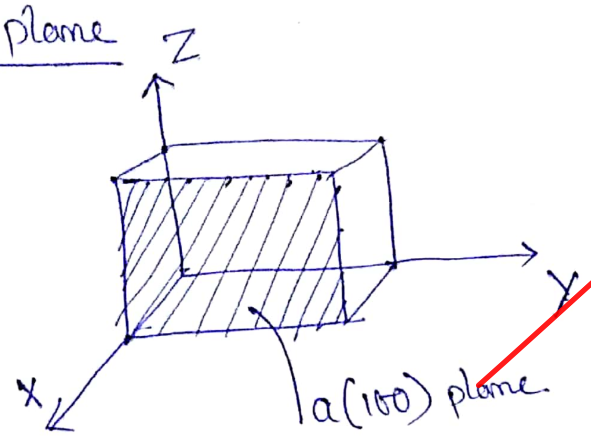
Close loop gain,

$$A_f = \frac{A}{D} = \frac{A}{1 + A\beta} = - \frac{g_{m_2} R_D}{1 + \frac{g_{m_2} R_D R_M}{(R_F + R_M)}}$$

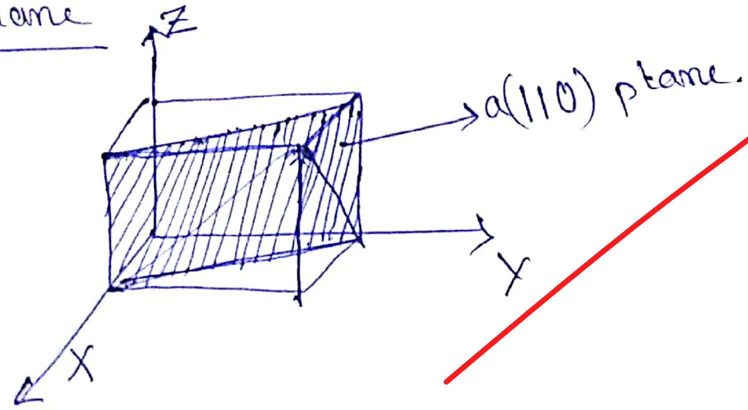
$$\boxed{A_f = - \frac{g_{m_2} R_D (R_F + R_M)}{R_F + R_M + g_{m_2} R_D R_M}}$$

(1) (c)

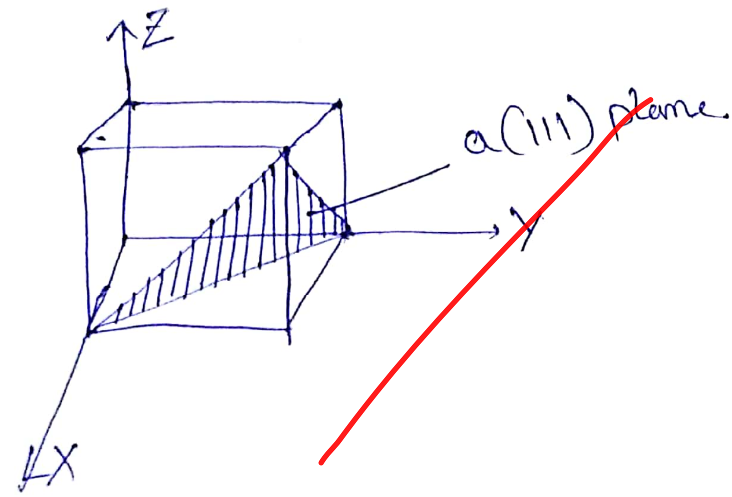
a(100) plane



a(110) plane



a(111) plane



Equivalent plane of (100)

Family of (100) plane

$= \{(100), (010), (001), (\bar{1}00), (0\bar{1}0), (00\bar{1})\}$

Therefore, Number of equivalent plane of (100) is

$\boxed{N_p = 6}$

Inter planer Separation

Given $r_{FCC} = 1.06\,\text{Å} = \frac{a}{2\sqrt{2}}$

a = lattice parameter.

$\Rightarrow a = 2\sqrt{2} \times 1.06\,\text{Å}$

$a \cong 3\,\text{Å}$

Inter planer Separation for (111) plane.

$$d = \frac{a}{\sqrt{h^2 + k^2 + l^2}} = \frac{3}{\sqrt{1^2 + 1^2 + 1^2}}\,\text{Å}$$

$$\boxed{d = \sqrt{3} = 1.732\,\text{Å}}$$

(1)(d) Given,

Field intensity

$H = 10^6\ A/m$

Temperature $T = (273+27) = 300K$

Boltman constant $K = 1.38 \times 10^{-23}\ J/K$

Bohr magneton $\mu_B = 9.27 \times 10^{-24}\ A/m^2$

Magnetic suscentibility

$$\chi_m = \frac{N \mu_0 \mu_r \mu_B^2}{3KT} \quad \text{——— (1)}$$

[For paramagnetic material $\mu_r = 1$]

⇒ Magnetization

$$M = N P_m = \chi_m H$$

$$\Rightarrow P_m = \frac{\chi_m H}{N} \quad \text{——— (2)}$$

From eqn (1) and (2) we get

Average magnetic momement

$$P_m = \frac{\mu_0 \mu_B^2}{3KT} H. \quad [\because \mu_r = 1]$$

$$\Rightarrow P_m = \frac{4\pi \times 10^{-7} \times (9.27 \times 10^{-24})^2}{3 \times 1.38 \times 10^{-23} \times 300} \times 10^6\ Am^2$$

$$\Rightarrow P_m = 8.695 \times 10^{-27}\ Am^2$$

$$\Rightarrow \boxed{P_m = 8.695 \times 10^{-27}\ Am^2}$$

1)(e)

Superconductivity

It is a state of material which has zero resistivity.

☐ When any ~~ma~~ material entered to normal state from superconducting state, ~~its~~ i.e. in transition state its <u>entropy increases</u>.

Again it shows, resistance to flow in current, and ~~low~~ allows magnetic flux to flows trough it.

Properties of Super Conductor

→ In Super Conductive state material exhibits zero resistivity.

→ It behave as a pure diamagnetic material.

→ Due to application of externer magnetic field Super condutivity can be detroyed, ~~And~~ at critical magnetic field which is depends on temperature,

$$H_c = H_0\left\{1-\left(\frac{T}{T_c}\right)^2\right\}$$

→ No thermoelectric activities performed in Superconducting state.

→ Transition temperature is depends on isotropic mass as

$$T_c \propto \frac{1}{\sqrt{M}}.$$

→ Super conductivity can be destroyed by applying sufficient current,

$$\boxed{I_c = H_c \times 2\pi r}$$

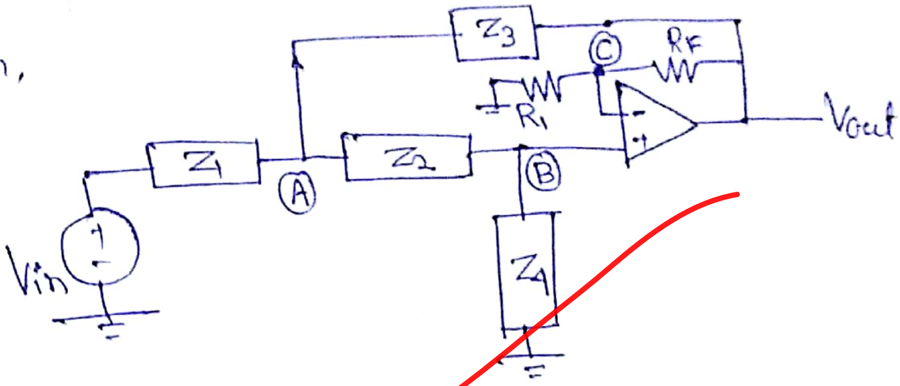
→ Basically, ~~and~~ non-condcucting material in normal temparature ~~So~~ shows Super Conductivity in lower temperature.

Given, ~~Iref = 100 uA,~~

~~therefore, $I_{DQ_3} = 100\,uA$~~

~~$I_{DQ_3} = M_p$~~

3 (a) Given diagram,



As, the given op-amp is ideal, considering virtual ground, $V_B = V_C$ ——— (1).

Applying KCL at node (A),

$$\frac{V_A - V_{in}}{Z_1} + \frac{V_A - V_B}{Z_2} + \frac{V_A - V_{out}}{Z_3} = 0.$$

$$\Rightarrow V_A\left(\frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3}\right) = \frac{V_{in}}{Z_1} + \frac{V_B}{Z_2} + \frac{V_{out}}{Z_3}$$

$$\Rightarrow V_A = \frac{\left(\frac{V_{in}}{Z_1} + \frac{V_B}{Z_2} + \frac{V_{out}}{Z_3}\right)}{\left(\frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3}\right)} \quad \text{——— (2)}$$

By KVC at node C, we get.

$$\frac{V_C - V_{out}}{R_F} + \frac{V_C}{R_1} = 0.$$

$$\Rightarrow V_C\left(\frac{1}{R_F} + \frac{1}{R_1}\right) = \frac{V_{out}}{R_F}$$

$$\Rightarrow V_C = \frac{V_{out}}{\left(1 + \frac{R_F}{R_1}\right)} \quad \text{——— (3)}$$

By KCL at node, (B) we get

$$\frac{V_B - V_A}{Z_2} + \frac{V_B - 0}{Z_4} = 0.$$

$$\Rightarrow V_B\left(\frac{1}{Z_2}+\frac{1}{Z_4}\right) = \frac{V_A}{Z_4}$$

$\Rightarrow$

from eqn (3)

$$\left[\because V_C = \frac{V_{out}}{\left(1+\frac{R_F}{R_1}\right)}\right]$$

$$[\text{And } V_B = V_C]$$

$$\Rightarrow \frac{V_{out}}{\left(1+\frac{R_F}{R_1}\right)} = \frac{V_A}{\left(1+\frac{Z_4}{Z_2}\right)}.$$

$$\Rightarrow V_A = \frac{\left(1+\frac{Z_4}{Z_2}\right)}{\left(1+\frac{R_F}{R_1}\right)} V_{out} \quad (4)$$

From eqn (2) and (4) we get,

$$\frac{\left(1+\frac{Z_4}{Z_2}\right)}{\left(1+\frac{R_F}{R_1}\right)} V_{out} = \frac{\left(\frac{V_{in}}{Z_1}+\frac{V_B}{Z_2}+\frac{V_{out}}{Z_3}\right)}{\left(\frac{1}{Z_1}+\frac{1}{Z_2}+\frac{1}{Z_3}\right)}$$

$$\Rightarrow \frac{\left(1+\frac{Z_4}{Z_2}\right)\left(\frac{1}{Z_1}+\frac{1}{Z_2}+\frac{1}{Z_3}\right)}{\left(1+\frac{R_F}{R_1}\right)} V_{out} = \frac{V_{in}}{Z_1} + \frac{V_{out}}{Z_3} + \frac{V_{out}}{Z_2\left(1+\frac{R_F}{R_1}\right)}$$

$$\because V_B = V_C = \frac{V_{out}}{\left(1+\frac{R_F}{R_1}\right)}.$$

$$\Rightarrow \frac{\left(1+\frac{Z_4}{Z_2}\right)\left(\frac{1}{Z_1}+\frac{1}{Z_2}+\frac{1}{Z_3}\right)}{\left(1+R_F/R_1\right)} = \frac{V_{in}}{V_{out}}\frac{1}{Z_1} + \frac{1}{Z_3} + \frac{1}{Z_2\left(1+\frac{R_F}{R_1}\right)}.$$

$$\Rightarrow \frac{V_{in}}{V_{out}} = Z_1\frac{\left(1+\frac{Z_4}{Z_2}\right)\left(\frac{1}{Z_1}+\frac{1}{Z_2}+\frac{1}{Z_3}\right)}{\left(1+\frac{R_F}{R_1}\right)} - \frac{Z_1}{Z_2\left(1+\frac{R_F}{R_1}\right)} - \frac{Z_1}{Z_3}$$

$$\Rightarrow \frac{V_{in}}{V_{out}} = \frac{\left(1+\cancel{\frac{Z_1}{Z_2}}+\cancel{\frac{Z_1}{Z_3}}+\frac{Z_4}{Z_2}+\frac{Z_4 Z_1}{Z_2^2}+\frac{Z_4 Z_1}{Z_2 Z_3}-\cancel{\frac{Z_1}{Z_2}}-\cancel{\frac{Z_1}{Z_3}}-\frac{R_F}{R_1}\frac{Z_1}{Z_3}\right)}{\left(1+\frac{R_F}{R_1}\right)}$$

$$\Rightarrow \boxed{\frac{V_{out}}{V_{in}} = \frac{\left(1+R_F/R_1\right)}{\left(1+\frac{Z_4}{Z_2}+\frac{Z_1 Z_4}{Z_2 Z_3}+\frac{Z_1 Z_4}{Z_2^2}-\frac{R_F}{R_1}\frac{Z_1}{Z_3}\right)}}$$

(3)(b)(i)

$$\overset{p\rightarrow}{(A)} \xleftrightarrow{\;a\;} \overset{\rightarrow E_0}{(A)}$$

Due to applied field atoms get polarized, dipole moment

$$p = \alpha E_0$$

~~Polarization~~

Due to dipole moment one atom will produce internal electric field to another atom place,

$$E_i = \frac{1}{4\pi\epsilon_0}\frac{2p}{a^3} = \frac{1}{4\pi\epsilon_0}\cdot\frac{2\alpha E_0}{a^3}$$

Therefore local field

$$E_{local} = E_0 + E_i = E_0 + \frac{1}{4\pi\epsilon_0}\frac{2\alpha E_0}{a^3}$$

$$\Rightarrow \frac{E_{local}}{E_0} = \left(1 + \frac{2\alpha}{4\pi\epsilon_0 a^3}\right)$$

Given $\alpha = 3\times10^{-40}\ Fm^2$

$a = 5\times10^{-10}\ m.$

$$= 1 + \frac{2\times3\times10^{-40}}{\left(\frac{5\times10^{-10}}{9\times10^{9}}\right)}$$

$$\frac{E_{local}}{E_0} = \left(1 + 1.08\times10^{-20}\right)$$

$$\boxed{\frac{E_{local}}{E_0} \cong 1}.$$

(ii) Given $\epsilon_r = 4.8$, $\tan\delta = 0.001$, $f = 50\ Hz.$

$E_0 = 60\ kV/cm$

Heat loss due to alternating field,

$$W_E = \frac{f\,\epsilon_r \tan\delta\ E_0^2}{1.8\times10^{12}} = \frac{50\times4.8\times0.001\times(60\times10^3)^2}{1.8\times10^{12}}\ W/cm^3$$

$$\boxed{W_E = 0.48\ mW/cm^3}$$

(3) (c) (i) Given $l = 0.25 m$

$N = 1000$ turns.

$A = 2.5 A$.

~~Mg~~ Due to current, 2.5 A, ~~mg~~ magnetic induction in vacuum

$$B_V = \mu_0 \frac{NI}{2\pi l} \quad [\because \text{for vacuum } \mu_r = 1]$$

And, when the solinoid placed in Oxigen.

$$B_O = \frac{\mu_0 \mu_r NI}{2\pi l}$$

Change in induction,

$$\Delta B = B_O - B_V = (\mu_r - 1)\frac{\mu_0 NI}{2\pi l} = 1.04 \times 10^{-8}$$

$$\Rightarrow \quad X_{mo} \times \frac{1000 \times 2.5 \times 4\pi \times 10^{-7}}{2\pi \times 0.25} = 1.04 \times 10^{-8}$$

Magnetic Susceplibitity of oxigen.

$$\boxed{X_{mo} = 0.52 \times 10^{-5}}$$

(ii) Optical properties of semi conducting nanoparticles

Properties of semiconducting nanoparticles are strongly influenced by a number of factors such as size, shape, surface, functionalization, doping, and interaction with other materials etc. The size-dependent optical properties of them is due to change in optical energy band gap, which is turn influences the surface plasmon resonance of the nanomaterial.

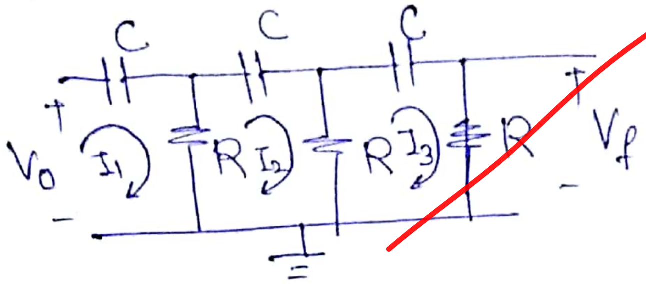
The optical band gap increases with the decrease in particle size, especially for semiconductor nanomaterials.

Another interesting property of semiconducting nanomaterials on the nanoscale is that they have optical properties which differ from the bulk material. It has been noticed that as the size of the particle is reduced, there is a shift in the absorption spectra to the blue.

By using semiconducting nanomaterial sensitivity of the photo detector can be increased by many times as a result existing uses like digital cameras, can be enhanced because because more 'pixels' can be placed on a sensor that with existing technology.

For semiconductor based nanomaterials, their function depends on change of refractive index with electric field. this feachers makes them high speed devices with low power consumption.

(4)
(a) Feedback circuit for the given oscillator,



By using mesh analysis,

$$(R+X_c)I_1 - RI_2 = V_0$$

$$-RI_1 + (2R+X_c)I_2 - RI_3 = 0$$

$$-RI_2 + (2R+X_c)I_3 = 0.$$

where, $\left[X_c = \frac{1}{j\omega C} \right]$

$$\begin{bmatrix} (R+X_c) & -R & 0 \\ -R & (2R+X_c) & -R \\ 0 & -R & (2R+X_c) \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} V_0 \\ 0 \\ 0 \end{bmatrix}$$

By using Cramer's rule,

$$I_3 = \frac{\begin{vmatrix} R+X_c & -R & V_0 \\ -R & 2R+X_c & 0 \\ 0 & -R & 0 \end{vmatrix}}{\begin{vmatrix} R+X_c & -R & 0 \\ -R & 2R+X_c & -R \\ 0 & -R & 2R+X_c \end{vmatrix}} = \frac{V_0(R^2)}{(R+X_c)\left[(2R+X_c)^2 - R^2\right] + R(-R)(2R+X_c)}$$

$$V_f = R \times I_3 = \frac{V_0 R^3}{R^3 + 6R^2X_c + 5RX_c^2 + X_c^3}$$

$$\beta = \frac{V_f}{V_0} = \frac{1}{1 + 6X_c/R + 5\left(\frac{X_c}{R}\right)^2 + \left(\frac{X_c}{R}\right)^3}$$

$$\beta = \frac{1}{\left(1 - \frac{5}{\omega^2R^2C^2}\right) + j\left(\frac{1}{\omega^3R^3C^3} - \frac{6}{\omega RC}\right)} \qquad \left[\because X_c = \frac{1}{j\omega RC}\right]$$

Close loop gain,

$$A\beta = \frac{\left(1+\frac{R_F}{R_i}\right)}{\left(1-\frac{5}{\omega^2R^2C^2}\right)+j\left(\frac{1}{\omega^3R^3C^3}-\frac{6}{\omega RC}\right)} \quad \text{--- (1)}$$

For oscillation, ~~sys~~ $A\beta$ should have linear phase, i.e. imaginary part should be zero. And also, $A\beta \geq 1$ for sustain oscillation.

Hence,

$$\frac{1}{\omega^3R^3C^3}-\frac{6}{\omega RC}=0,$$

$$\Rightarrow \omega = \frac{1}{\sqrt{6}RC} \quad \text{--- (2)}$$

$$\Rightarrow \boxed{f = \frac{1}{2\pi\sqrt{6}RC}}$$

And also,

$$|A\beta| \geq 1$$ for sustain oscillation.

From, eqn (1) and (2) we get,

$$\left|\frac{\left(1+\frac{R_F}{R_i}\right)}{(1-5\times 6)}\right| \geq 1 \qquad \left[\because \omega RC = \frac{1}{\sqrt{6}}\right]$$

$$\left(1+\frac{R_F}{R_i}\right) \geq 29$$

$$\Rightarrow \boxed{\frac{R_F}{R_i} \geq 28}$$

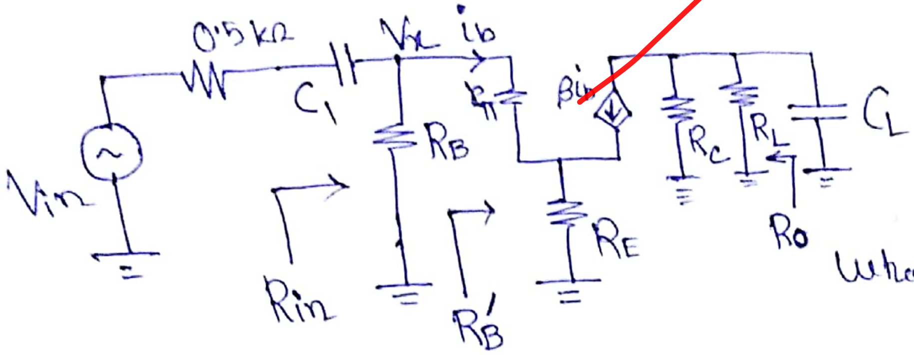
Condition for oscillation.

4 (b) ~~G.P~~ Given, $g_m = 40\ mA/V$

and $\beta = 100$

therefore, $r_\pi = \frac{\beta}{g_m} = 2.5\ k\Omega$

AC equivalent circuit can be drawn as,



where $R_B = (40 \| 40)\ k\Omega$

$R_B = 20\ k\Omega$

To determine R_B', apply KVL in the input loop,

$$V_x = i_b r_\pi + (1+\beta) R_E$$

$$\Rightarrow R_B' = \frac{V_x}{i_b} = r_\pi + (1+\beta) R_E$$

[$\because r_\pi = 2.5\ k\Omega$
And Given $R_E = 0.5\ k\Omega$
$\beta = 100$]

$$\Rightarrow R_B' = 2.5 + (100+1)\ 0.5$$

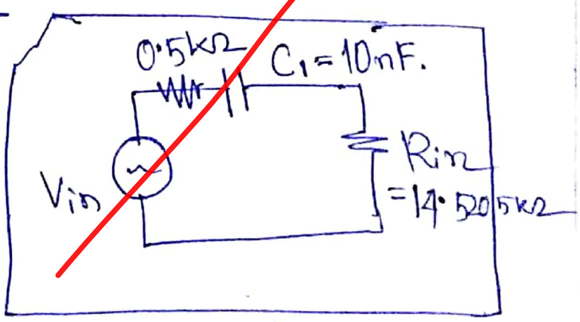
$$R_B' = 53\ k\Omega$$

Therefore input impedence,

$\because R_B = 20\ k\Omega$

$$R_{in} = (R_B \| R_B') = (20 \| 53)\ k\Omega$$

$$R_{in} = 14.5205\ k\Omega$$



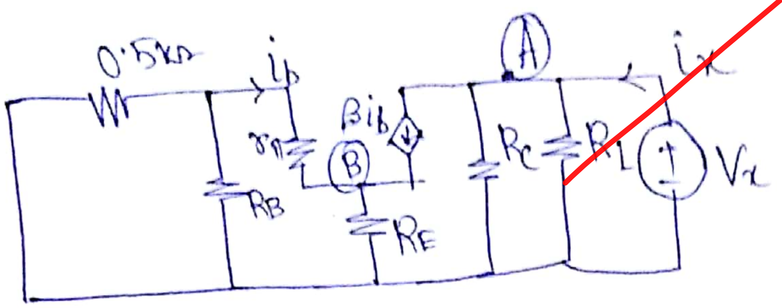
Equivalent time constant for, input loop

$$\tau_{in} = (R_{in} + 0.5)\ C_1$$

$$= (14.5205 + 0.5) \times 10^{+3} \times 10^{-8}$$

Lower Cutoff frequency is $\boxed{f_L = \frac{1}{2\pi \tau_1} = \frac{10^5}{2\pi (15.0205)} = 1.06\ kHz}$

To, determine R_o, dissable the input source, and replaced by short circuit. And connect a voltage source V_x with current across output.



By using, KCL at node (A), we get,

$$\frac{V_x}{(R_C \| R_L)} + \beta i_b = I_x$$

$$i_b = \frac{I_x}{\beta} - \frac{V_x}{(R_C \| R_L)\beta} \qquad (1)$$

~~By using KCL at node, (B) we get,~~

$$\cancel{\frac{R_E}{R_E + \{(R_B \| 0.5) + r_\pi\}} + \beta i_b =}$$

As the no input V_i source is connected in input loop. ~~Source,~~

$i_b = 0$,

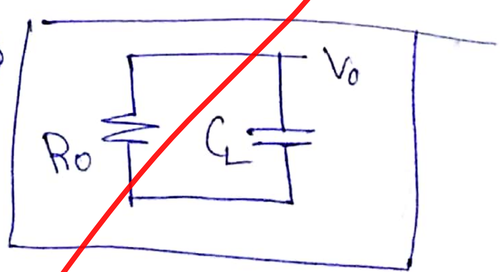
therefore from eqn (1) we get.

$$R_o = \frac{V_x}{I_x} = (R_C \| R_L) = (2 \| 2) = 1\,k\Omega$$

$[\because R_C = R_L = 2\,k\Omega]$

Therefore, higher cutoff frequency,

A



$$f_H = \frac{1}{2\pi R_o C_L} = \frac{1}{2\pi \times 10^3 \times 15 \times 10^{-9}}$$

$$f_H = 10.61\ kHz.$$

$$\text{Bandwidth } (f_H - f_L) = (10.61 - 1.06)\ kHz$$

$$\boxed{BW = 9.55\ kHz}$$

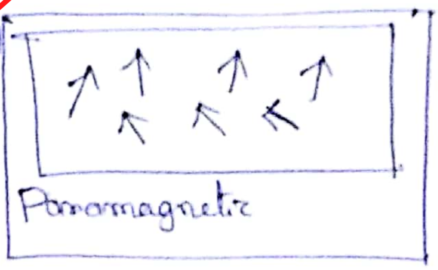
4 (c)

Classification of magnetic material

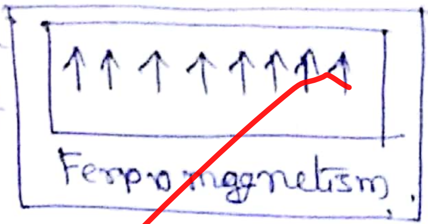
According to magnetic behaviour material can be classified into —
diamagnetic, paramagnetic, ferromagnetic, ~~and~~ antiferromagnetic and ferrimagnetic.

For diamagnetic material, its origin in the circulating charges in the orbits and hence, all the material exhibit diamagnetism.

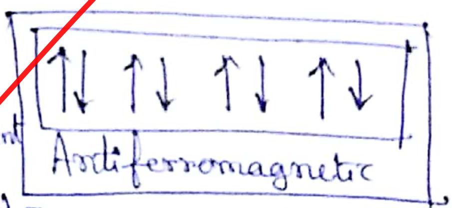
When the individual dipole do not interact with each other and randomly distributed in absense of electric field paramagnetism arises.



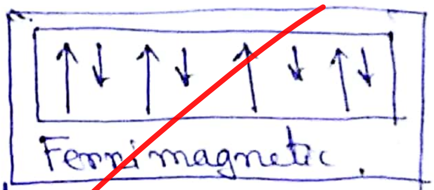
If interact leads to parallel alignment of the neighbouring magnetic moments exhibits ferromagnetism.



In case of ~~pear~~ antiparallel and equal in magnitude alignment of dipoles lead to antiferromagnetism.



If dipoles are align antiparallel and they the different in magnitude leads to ferrimagnetism.



Properties of ferromagnetic material

→ Permeability is greater than 1

→ Magnetic susceptibility is large and positive.

→ All Ferromagnetic material becomes paramagnetic above a temperature called Curie temperature

→ In ferromagnetic materials, the magnetic lines of forces due to the applied magnetic field are strongly attracted towards the material

→ ~~Mg~~ Magnetic susceplibility decreases with the rise in temperature according to Curie - Weiss law.

→ The source of ferromagnetism is spin of electron

→ Ferromagnetic materials like Fe, Co, Ni have incomplete inner shell. These shells can be completed by using Hund's rule.

→ Ferromagnetism is the property of a material to be strongly attracted to a magnetic field and to become a powerfull magnet.

☐ Given $\mu = 4.6\mu_0$ and $\vec{B} = 10e^{-y}\hat{a}_z$

(i) Therefore, $\mu_r = 4.6$, $\chi_m = (\mu_r - 1) = 4.6 - 1$

$$\boxed{\chi_m = 3.6}$$

(ii) $\vec{H} = \dfrac{\vec{B}}{\mu} = \dfrac{10e^{-y}\hat{a}_z}{4.6 \times 4\pi \times 10^{-7}} = 1.73 \times 10^{6} e^{-y}\hat{a}_z$

$$\boxed{\vec{H} = 1.73 \times 10^{6} e^{-y}\hat{a}_z} \text{ A/m}$$

(iii) $\vec{M} = \chi_m \vec{H} = 3.6 \times 1.73 \times 10^{6} e^{-y}\hat{a}_z$

$$\boxed{\vec{M} = 6.228 \times 10^{6} e^{-y}\hat{a}_z} \text{ A/m}$$

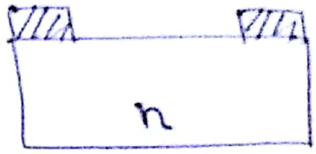
5)(a)

~~Given~~ +

Given, $\rho_n = \frac{1}{\sigma_n} = 0.5\ \Omega\text{cm}.$

$\sigma_n = 2\ S/cm$

$\mu_n = 1300\ cm^2/V\text{-}s.$

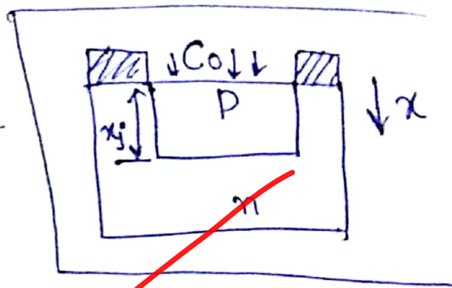


Concentration of ~~electro~~

$$n = \frac{\sigma_n}{q(\mu_n)} = \frac{2}{1.6\times10^{-19}\times 1300}$$

$$n = 9.6153\times10^{15}\ cm^{-3}$$

At surface, concentration is maximum and keep on decreasing ~~as~~ ~~if~~ with depth.



at $x = x_j$, Concentration of $p = n$

for $x > x_j$, $n > p$

for $x < x_j$, $p > n$.

By the Solution of Fick's Law net concentration at $x = x_j$

$$C = C_0\,\text{erfc}\left(\frac{x_j}{2\sqrt{Dt}}\right)$$

Given

$C_0 = 5\times10^{18}\ cm^{-3}$

$t = 2\times60\times60\ Sec.$

$x_j = 2.7\times10^{-4}\ cm$

$\Rightarrow 9.6153\times10^{15} = 5\times10^{18}\ \text{erfc}\left(\frac{2.7\times10^{-4}}{2\sqrt{D\times7200}}\right)$

$\Rightarrow 1.92\times10^{-3} = \text{erfc}\left(\frac{2.7\times10^{-4}}{2\sqrt{D\times7200}}\right)$

Given $[\because \text{erfc}(2.2) = 1.92\times10^{-3}]$

$\Rightarrow \frac{2.7\times10^{-4}}{2\sqrt{D\times7200}} = 2.2$

$\Rightarrow \boxed{D = 5.23\times10^{-13}\ cm^2/Sec}$ ← Diffusion Constant of boron

(5)
(b) Given $N_a = 2\times10^{17}\ cm^{-3}$

$N_d = 3\times10^{17}\ cm^{-3}$

As $N_d > N_a$, net concentration of electron,

$$n = (N_d - N_a) = (3\times10^{17} - 2\times10^{17})$$

$$\Rightarrow n = 10^{17}\ cm^{-3}$$

(i)

Given $\mu_n = 350\ cm^2/V\text{-}s.$

~~Surface density~~ of $t = 2\mu m$ thick arsenic Layer,
Sheet resistance

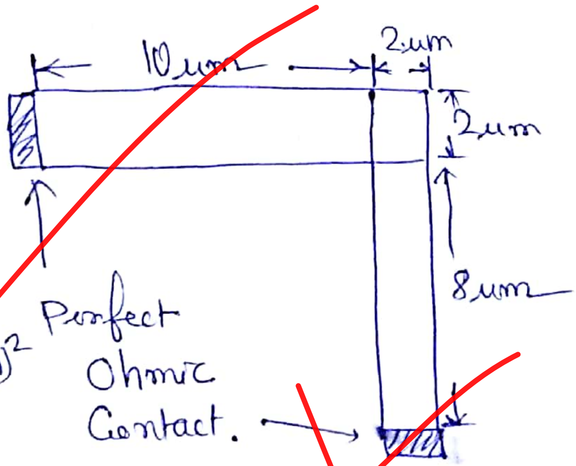
$$R_s = \frac{1}{\sigma} \times t$$

$$R_s = \frac{t}{n \times \mu_n \times q} = \frac{2\times10^{-4}}{10^{17}\times350\times1.6\times10^{-19}}$$

$$\rightarrow R_s = 3.57\times10^{-5}\ \Omega/cm^2$$

(ii)

Surface area of the layout pattern,



$$A = (10\times2 + 2\times2 + 8\times2)\ (\mu m)^2$$

$$A = 40\times10^{-8}\ cm^2$$

Therefore resistance of the given IC

$$R_c = R_s \times A = 3.57\times10^{-5} \times 40\times10^{-8}\ \Omega$$

$$\boxed{R_c = 1.428\times10^{-11}\ \Omega}$$

Q (5)(c)

Given message signal

$$m(t) = A\tanh(\beta t) = A\cdot\left(\frac{e^{\beta t}+e^{-\beta t}}{e^{\beta t}-e^{-\beta t}}\right)$$

$$\Rightarrow m(t) = A\cdot\left(\frac{e^{2\beta t}+1}{e^{2\beta t}-1}\right)$$

Taking derivative both side w.r.t time t, we get.

$$\frac{dm(t)}{dt} = A\,\frac{(e^{2\beta t}-1)e^{2\beta t}\times 2\beta - e^{2\beta t}\cdot 2\beta(e^{2\beta t}+1)}{(e^{2\beta t}-1)^2}$$

$$\frac{dm(t)}{dt} = A\,2\beta e^{2\beta t}\,\frac{(-2)}{(e^{2\beta t}-1)}.$$

$$\frac{dm(t)}{dt} = -4A\beta\,\frac{(e^{2\beta t}-1)+1}{(e^{2\beta t}-1)} = -4A\beta - \frac{4A\beta}{e^{2\beta t}-1}$$

Let, $F(t) = \frac{dm(t)}{dt} = -4A\beta - \frac{4A\beta}{e^{2\beta t}-1}$

To find maximum value of $F(t)$,

$$\frac{dF(t)}{dt} = +\frac{4A\beta(2\beta)}{(e^{2\beta t}-1)^2} = 0.$$

$$e^{2\beta t} \to \infty$$

Therefore, $\left|\frac{dm(t)}{dt}\right|_{max} = |-4A\beta| = 4A\beta.$

To avoid slope ~~oper~~ overload,

$$\frac{\Delta_{min}}{T_s} \geq \left|\frac{dm(t)}{dt}\right|_{max}$$

$$\Rightarrow \Delta_{min} \geq T_s \times 4A\beta$$ [T_s = Sampling interval for the delta modulator]

$$\Rightarrow \boxed{\Delta_{min} \geq 4A\beta T_s}$$

(5) (d) Given,

$N_a = 2\times10^{16}\ cm^{-3}$

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

for Silicon $n_i = 1.5\times10^{10}\ cm^{-3}$

Build in potential

$$V_o = V_T \ln\left(\frac{N_a N_d}{n_i^2}\right) = 0.0259 \times \ln\left(\frac{2\times10^{16}\times10^{16}}{1.5^2\times10^{20}}\right)$$

$$V_o = 0.7126\ V$$

Depletion width for reverse bias of 15 V

Given $\varepsilon_{si} = 11.9\times\varepsilon_o$.

$$W = \sqrt{\frac{2\times\varepsilon_{si}\times V_B}{q}\left(\frac{1}{N_a}+\frac{1}{N_d}\right)}.$$

$$= \sqrt{\frac{2\times11.9\times8.854\times10^{-14}\times(15+0.7126)}{1.6\times10^{-19}}\left(\frac{1}{2\times10^{16}}+\frac{1}{10^{16}}\right)}$$

$$= 1.762\times10^{-4}\ cm.$$

Diffusion length for,

Given
$D_n = 20\ cm^2/s$
$\tau_n = 10^{-8}$ sec
$D_p = 12\ cm^2/sec$
$\tau_p = 10^{-8}$ sec

Electron $L_n = \sqrt{D_n\times\tau_n}$

$$= \sqrt{20\times10^{-8}}$$

$$= 4.472\times10^{-4}\ cm$$

Hole $L_p = \sqrt{D_p\times\tau_p} = \sqrt{12\times10^{-8}}$

$L_p = 3.464$ cm

Given $G_L = 10^{22}$

$A = 10^4\ cm^2$

photo current

$$I_p = q G_L A (W+L_n+L_p)$$

$$I_p = 1.6\times10^{-19}\times10^{22}\times10^{-4}(1.762+4.472+3.464)\times10^{-4}$$ → $A = 10^{-4}\ cm^2$

$$\boxed{I_p = 0.155\ mA}$$

5(e) Let consider for p-side,

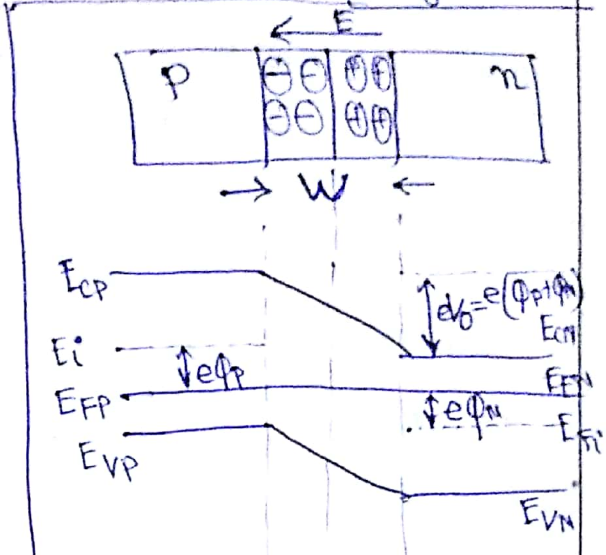


Fig. a.

Drift current due to induce electricfield, E

$$J_d = \cancel{qE\mu p}$$

$$J_d = \sigma_p E$$

$$J_{drift} = q\, p(x)\mu_p\left(-\frac{dV}{dx}\right) \quad \text{——— (1)}$$

Diffusion current,

$$J_{diffusion} = q D_p \frac{dp(x)}{dx} \quad \text{——— (2)}$$

At equilibrium,

$$J_{drift} + J_{diffusion} = 0$$

$$\Rightarrow \quad q\, p(x)\mu_p\left(-\frac{dV}{dx}\right) + q D_p \frac{dp(x)}{dx} = 0.$$

$$\Rightarrow \quad dV = \frac{D_p}{\mu_p}\frac{dp(x)}{p(x)}.$$

$\Rightarrow$ $\int$ Integrating both side ~~in~~ ~~the~~ from the depletion edge of n-side to p-side

$$\int dV = V_T \int_{P_{no}}^{P_{po}} \frac{dp}{p}$$

$\left[\because \frac{D_p}{\mu_p} = V_T = \text{Thermal voltage}\right]$

P_{po} = Concentration of hole in p region

$\Rightarrow P_{po} = N_a$

P_{no} = Concentration of hole in n region

$\left(P_{no} = \frac{n_i^2}{N_d}\right)$

$$\Rightarrow \quad V_0 = V_T\left[\ln p\right]_{P_{no}}^{P_{po}}$$

$$V_0 = V_T\left[\ln P_{po} - \ln P_{no}\right]$$

$$\boxed{V_0 = V_T \ln\left(\frac{N_a N_d}{n_i^2}\right)}$$

From the figure, we can conclude that build in potential, is the sum of work function potential for N-region ϕ_N and P-region ϕ_P.

i.e. $V_0 = (\phi_N + \phi_P)$.

Where, Work function potential is the shift of Fermi level from intrinsic level.

And for Non-degenerative droping ~~Fermi~~ Fermi level reside above the valence band (for p-type) and below the Conduction band (for n-type).

Therefore for non-degenerative type of droping.

$(eV_0) < \text{Band gap}$.

6 (a) Let assume a source is emitting M number of symbol $\{S_1, S_2 \dots S_M\}$ with probability $\{P(x_1), P(x_2) \dots P(x_M)\}$

Entropy of the symbols

$$H = -\sum_{i=1}^{M} P(x_i) \log_2 P(x_i).$$

By using Jensen's inequality, Given a Convex function ϕ

$$\lambda_i, y_i > 0$$

then

$$\phi\left[\sum_{i=1}^{M} \lambda_i \cdot y_i\right] \leqslant \sum_{i=1}^{M} \lambda_i \phi[y_i] \quad \text{——— (1)}$$

where $\phi[z] = \exp[z]$

Let $\lambda_i = P(x_i)$ and $y_i = -\log_2 P(x_i)$.

Then, From the eqn (1) we get,

$$\exp\left[\sum_{i=1}^{M} \lambda_i y_i\right] \leqslant \sum_{i=1}^{M} \lambda_i \exp[y_i]$$

$$\Rightarrow \exp\left[\sum_{i=1}^{M} P(x_i)\{-\log_2(P(x_i))\}\right] \leqslant \sum_{i=1}^{M} P(x_i) \exp[-\log_2 P(x_i)]$$

$$\Rightarrow \cancel{\exp(H) \leqslant \sum_{i=1}^{M} P(x_i) \cdot \exp[-\log_e\{P(x_i)\}\log_2 e\}]}$$

$$\Rightarrow \cancel{\exp(H) \leqslant \sum_{i=1}^{M} P(x_i)\left[\frac{1}{P(x_i)}\right]^{\log_2 e}}$$

$$\Rightarrow \cancel{H \leqslant \sum_{i=1}^{M} m P(x_i) \div (\log_2 e) \cdot m}$$

$$H \leq \log_2 \left[\sum_{i=1}^{M} 1\right]$$

$$\Rightarrow H \leq \log_2 M$$

Therefore $\boxed{H_{max} \leq \log_2 M}$ <proved>

(ii)

$S_1 \rightarrow$ Symbol dot

$S_2 \rightarrow$ Symbol dash

Given,

$P(S_1) = 2\,P(S_2)$ ——— (1)

And $T_{S_1} = 0.2$ sec.

$T_{S_2} = 3 \times T_{S_1} = 0.2 \times 3 = 0.6$ sec.

Time between symbol

$T_g = 0.2$ s.

~~Time per~~

As the source emitting only symbol S_1 and S_2

$\Rightarrow P(S_1) + P(S_2) = 1$

$\Rightarrow P(S_2) + 2P(S_2) = 1 \quad [\because P(S_1) = 2P(S_3)]$

$\Rightarrow P(S_2) = 1/3$

And, $P(S_1) = 1 - 1/3 = 2/3$

Average time period,

$T = T_{S_1} P(S_1) + T(S_2) \cdot P(S_2) + T_g$

$= 0.2 \times 2/3 + 0.6 \times \frac{1}{3} + 0.2$

$T = 0.5333$ sec.

bit rate $(r) = \frac{1}{T} = \frac{1}{0.5333} = 1.875$ ~~bit~~ symbol/sec.

Entropy of Symb source,

$$H = -\sum_{i=1}^{2} P(S_i)\log_2 P(S_i)$$

$$= -\left[\frac{2}{3}\log_2(2/3) + \frac{1}{3}\log_2(1/3)\right] \text{ bit/symbol.}$$

$$H = 0.9183 \text{ bit/symbol.}$$

Information rate

$$I = r H$$

$$I = 1.875 \times 0.9183$$

$$\boxed{I = 1.722 \text{ bit/sec}}$$

(6) (b) (i)

5% of the 10^{10} cm^{-3} silicon relplace gallium. in GaAs.

Therefore donor Concentration

$$N_d = 5\% \text{ of } 10^{10} \text{ cm}^{-3}$$

$$\boxed{N_d = 5\times 10^8 \text{ cm}^{-3}}$$

95% of the 10^{10} cm^{-3} silicon replace Arsenic

therefore Acceptor Concentration

$$N_a = 95\% \text{ of } 10^{10} \text{ cm}^{-3}$$

$$\boxed{N_a = 9.5\times 10^9 \text{ cm}^{-3}}$$

(ii) As $N_a > N_d$, hence the composite semiconductor will act as p-type and net hole concentration

$$p \cong (N_a - N_d) \qquad \text{As } (N_a - N_d) \gg n_i$$

$$\Rightarrow p = (0.5\times10^{9} - 5\times10^{8})$$

$$\Rightarrow \boxed{p = 9\times10^{9}\ \text{cm}^{-3}}$$

electron concentration,

$$n = \frac{n_i^2}{p} = \frac{(9\times10^6)^2}{9\times10^9}\ \text{cm}^{-3}$$

Given $n_i = 9\times10^{6}\ \text{cm}^{-3}$

$$\Rightarrow \boxed{n = 9\times10^{3}\ \text{cm}^{-3}}$$

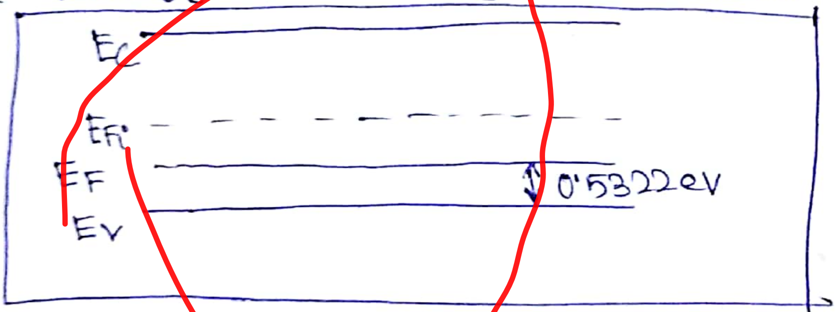
~~And shift of~~ And distance of Fermi level from valence band

$$(E_F - E_V) = V_T \ln\left(\frac{N_V}{p}\right) \qquad [N_V = 7\times10^{18}\ \text{cm}^{-3}]$$

$$= 0.026 \ln\left(\frac{7\times10^{18}}{9\times10^{9}}\right) \qquad [V_T = 0.026\ \text{eV}]$$

$$\boxed{E_F - E_V = 0.5322\,\text{eV}}$$

~~Band~~ Energy band diagram is shown below



(iii) Conductivity of ~~GaAs~~ GaAs

Given
$\mu_p = 400\ \text{cm}^2/\text{V-s}$
$\mu_n = 8800\ \text{cm}^2/\text{V-s}$

$$\sigma = q\times(n\mu_n + p\mu_p)$$

$$\sigma = 1.6\times10^{-19}\left(8800\times9\times10^{3} + 400\times9\times10^{9}\right)$$

$$\boxed{\sigma = 5.76\times10^{-7}\ \text{S/cm}}$$

6 (C)

(i) Process to produce (EGS) from MGS (Metallurgical-grade Silicon)

First, hydrocloronation done to produce triclorosilane ($SiHCl_3$) in a fluid bed reactor via reaction

$$Si + 3HCl \xrightarrow{300^\circ C} SiHCl_3 + H_2.$$

This reaction takes placed at around 300°C. The resulting Trichlorosilane ~~k~~ is already much purer than the raw Si; it is a liquid with a boiling point 31.8°C.

Second, $SiHCl_3$ is distilled resulting in extremely pure trichlorosilane.

~~Third~~, SiH_4 + heat $\xrightarrow{900^\circ C}$ $Si + 2H_2$

Third, highly-pure Si is produced by the Siemens process or, to use modern name by a Chemical vapor Diposition process, a process which we will encounter more often, ~~in the~~.

$$SiHCl_3 + 2H_2 \Rightarrow 2Si + 6HCl.$$

The produced electronic grade silicon (EGS) deposited on a ~~bar~~ resistance heated silicon rod which collected as cutting the rod or crushing it.

(6) (C) (ii) Required, boron Concentration

$$C_s = 10^{16} \text{ atoms}/cm^3$$

Segregation coefficient

$$K_o = 0.8$$

~~Req~~ Therefore,

Initial Concentration of Boron in melt

$$C_l = \frac{C_s}{K_o} = \frac{10^{16}}{0.8} = 1.25\times10^{16} \text{ atoms}/cm^3$$

$$\boxed{C_l = 1.25\times10^{16} \text{ atoms}/cm^3}$$

- Initial load in crucible

$$M_s = 60 kg. = 6\times10^4 g.$$

Density of molted silicon $(d_s) = 2.53 g/cm^3$.

Volume of molted silicon

$$V_s = \frac{M_s}{d_s} = \frac{6\times10^4}{2.53} cm^3$$

$$V_s = 2.37\times10^4 \ cm^3$$

Number of Boron atoms in the melt is

$$N_B = V_s \times C_L = 2.37\times10^4 \times 1.25\times10^{16} \text{ atoms}$$

$$N_B = 2.9644\times10^{20} \text{ atoms}$$

Amount of Boron to be added

$$W_B = \frac{2.9644\times10^{20}\times10.8}{6.023\times10^{23}}$$

Atomic weight of Boron = 10.8 g/mol

$$\boxed{W_B = 5.32\times10^{-3} g}$$