1. What is Fermi energy level? Explain the position of Fermi energy level in intrinsic and extrinsic semiconductors!

A) <u>Fermi energy level</u> :- The highest energy level that an electron can occupy at the absolute zero temperature is known as Fermi energy level. The Fermic energy level lies between the valance band and conduction band because at absolute zero temperature, the electrons are all in the lowest energy state.

<u>Fermi level in instrinsic semiconductor</u> :- (E_f)

$$n_i = p_i$$

$$N_c \cdot e^{-(E_c - E_f)/KT} = N_v e^{-(E_F - E_v)/KT}$$

$$\ln \frac{N_C}{N_V} = \frac{E_c + E_V - 2E_f}{KT}$$

$$E_F = \frac{E_c + E_V}{2} - \frac{KT}{2} \ln \frac{N_c}{N_v}$$

$$\boxed{E_f = \frac{E_c + E_V}{2}.}$$

<u>Fermi level in Extrinsic Semiconductor</u> :-

For n-type :-

$$E_F = E_c - KT \ln \frac{N_c}{N_D}$$

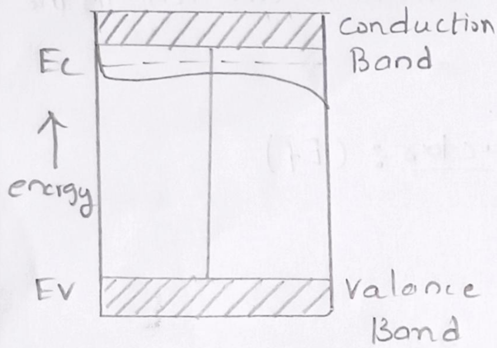
$$\boxed{N_D = N_c e^{-(E_c - E_F)/KT}}$$

For P-type:

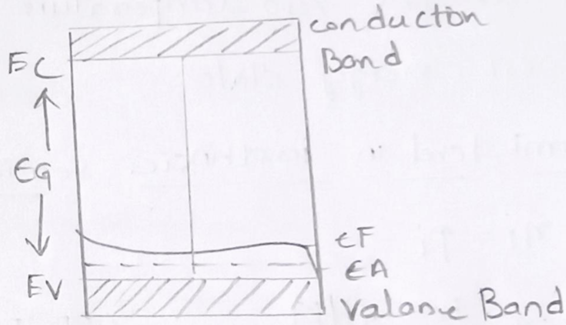
$$E_F = E_V + KT \ln \frac{N_C}{N_A}$$

$$\boxed{N_A = N_V \, e^{-(E_F - E_V)/KT}}$$

For N-type:



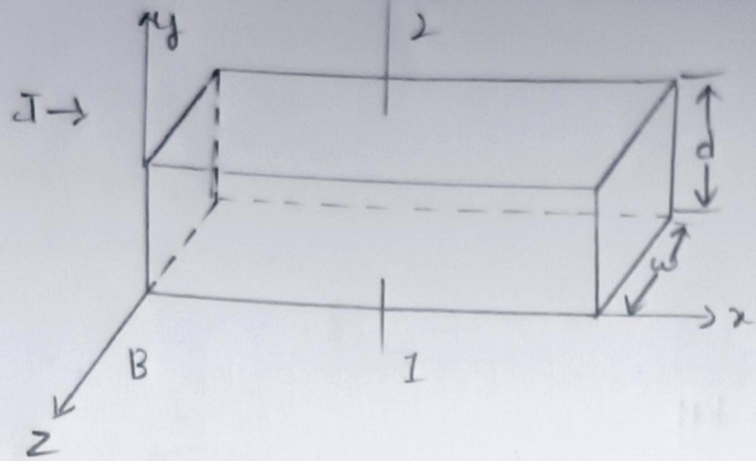
For P type:



As the temperature increases in the P-type, n-type semiconductors EF progresivly moves towards the middle of the Forbidden Energy gap.

2. a) Explain Hall effect in semiconductors.

A) Hall Effect: When a current-carrying conductor or a semiconductor is introduced to a perpendicular magnetic field, a voltage can be measured at the right angle to the current path. This effect of obtaing a measurable voltage is known as Hall Effect.



* When a transverse magnetic field 'B' is applied to a semiconductor carrying current 'i' an electric field 'E' is induced in the direction perpendicular to both I & B.

* The schematic arragement of the semiconductor under the equilibrium condition the electric field intensity 'E' due to the Hall effect must exert a force on a carrier of charge 'q' which just balance the magnetic field is.

$$qE = Bqv_d \quad -(1)$$

where v_d is Drift velocity

The electric intensity due to hall effect is

$$E = \frac{V_H}{d}$$

current density, $J = ev_d$ (conductivity)

$$J = \frac{I}{wd} \text{ (with Area)}$$

$$V_H = Ed$$

$$= Bv_d d.$$

$$= \frac{BJd}{P}.$$

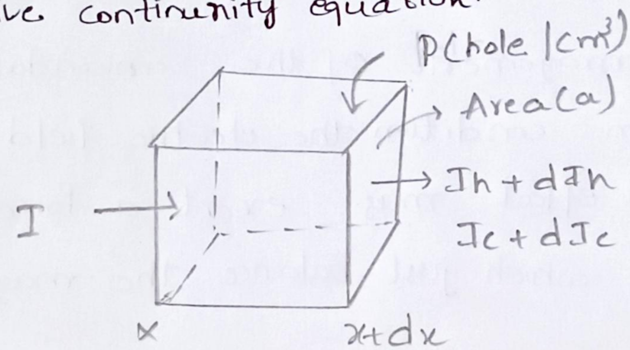
$$= \frac{BI}{P\omega}.$$

Hall coefficient = R_H

$$R_H = \frac{1}{P}$$

$$\boxed{V_H = \frac{R_H}{\omega} BI}$$

b) Derive continuity equation.



* The continuity equation as applied to Semiconductor describes how the carrier concentration in a given elemental volume of the crystal varries with time and distance.

* The variation in density is atributal to two basic causes :

1. the rate of generation and loss by recombination of carries with in the element

2. Drift of carriers into or out of the element

A = Area

length = dx

hole = p

current hole = I_p

$I_p + dI_p$ is distance travelled from x to $x+dx$

$\frac{dI_p}{q}$ (carrier charge)

$$J_p = \frac{I_p}{A}$$

$$\boxed{\frac{1}{qA} \cdot \frac{dI_p}{dx} = \frac{1}{q} \frac{dJ_p}{dx}}$$

$$\frac{\partial p}{\partial t} = \frac{-p-p_o}{\tau_p} - \frac{1}{q} \frac{\partial J_p}{\partial x} \qquad \left[J_p = -q D_p \frac{dp}{dx} + v_p \mu_p p E\right]$$

$$\boxed{\frac{\partial p}{\partial t} = \frac{-p-p_o}{\tau_p} + D_p \frac{d^2 p}{dx^2} - \mu_p \frac{d(pE)}{dx}}$$

Similarly,

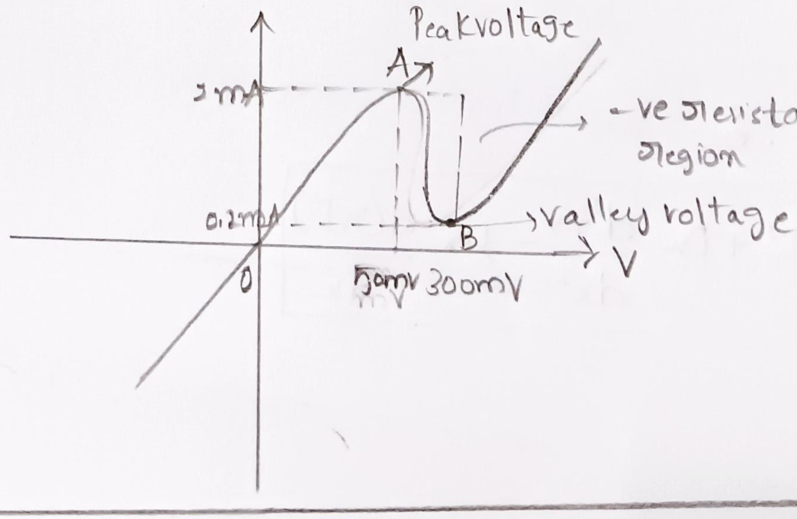
For electrons ÷ $\bar{e}$

$$\boxed{\frac{\partial n}{\partial t} = \frac{n-n_o}{\tau_n} + D_n \frac{d^2 n}{dx^2} - \mu_n \frac{d(nE)}{dx}}$$

3. Explain the operation of Tunnel diode with the help of its energy band diagram.

A) Tunnel Diode: The Tunnel diode is a thin junction diode which exhibits -ve resistance under low forward bias condition. An ordinary PN Junction has an impurity concentration of about 1 part in 10^8. If the concentration of impurity atoms is greatly increased to the level of 1 part in 10^3. The device characterstics are completely changed the width of the junction barrier varies inversely as the square root of impurity concentration For such root of impurity concentration. For such thin Potential energy barrier the electrons will penetrate through the junction rather than surmounting them, This quantum Mechanical behaviour is refered to as Turnaline. And Hence these High impurity density PN Junction devices are called Tunnel Diode

VI Characterstics Of Tunnel Diode:



Symbol of Tunnel Diode:-

Applications:-

1. As logic Memory storage Device
2. As microwave oscillator
3. As an amplifier
4. Relaxation oscillator circuit
5. As an ultra high speed switch

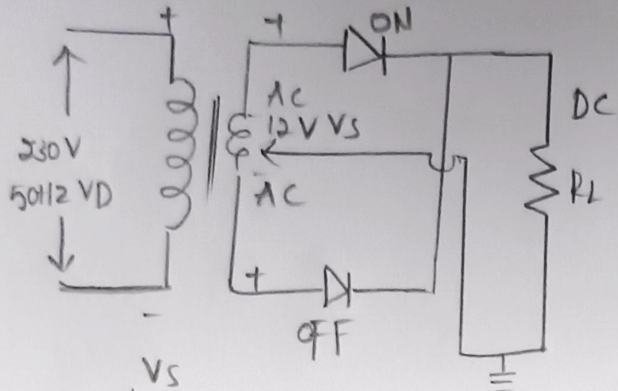
Advantages:-

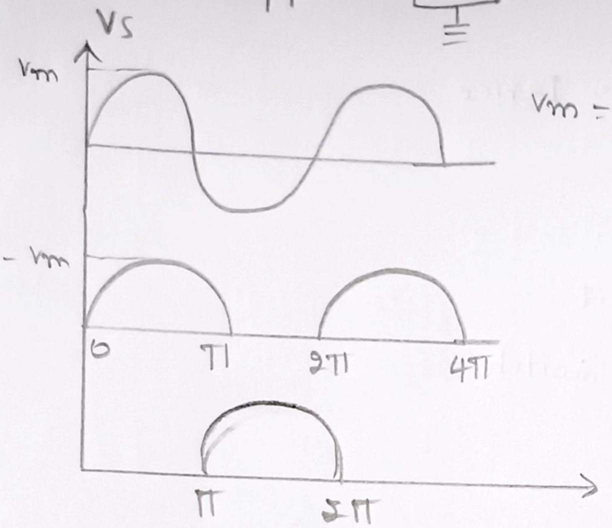
* Low noise
* High speed
* Low power
* Easy to operation

Disadvantages:-

* Voltage range over which it can be operated is one volt or less
* Being a two terminal device there is no isolation between the input and output circuit.

b) Derive the characterstics of Full wave rectifier.

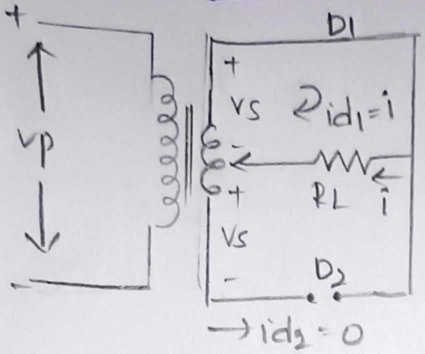




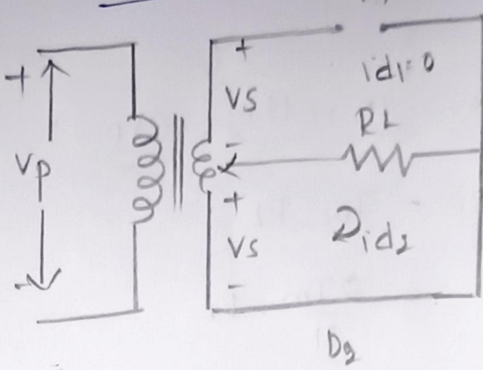
$$V_m = \int_0^{2\pi} \sin\alpha \, d\alpha$$

A Full wave rectifier conducts during both +ve & -ve cycles of the input the output of Full wave rectifier contains only +ve cycle. The -ve cycle of the input are also converted into +ve cycle. During +ve half cycle the diode D_1 will be forward Bias and act as a short circuit the diode D_2 will be reverse biased and acts as an open circuit. The current $I_{D_2} = 0$.

+ve Half cycle :-



-ve Half cycle :-



During the -ve Half cycle the diode d_1 will be reversed Biased and acts as a open circuit and the diode d_2 will be Forward biased which acts as a short circuit the diode current $i_{d1} = 0$ and the current through the load resistance $i = i_{d2}$. The directions of current i_{d1} & i_{d2} through the load resistance RL is same during +ve & -ve Half cycles. Therefore the -ve Half cycle of input will also be converted into +ve cycle

$$i = |I_m \sin\alpha|$$

Average o/p current (I_{DC}) :-

$$I_{DC} = \frac{1}{T} \int_0^T i \, d\alpha$$

$\because T = \pi$.

$$= \frac{1}{\pi} \int_0^{\pi} \cancel{\sin} \, I_m \sin\alpha \, d\alpha$$

$$= \frac{I_m}{\pi} \left[-\cos\alpha \right]_0^{\pi}$$

$$\therefore \boxed{I_{DC} = \frac{2I_m}{\pi}}$$

Average o/p voltage (V_{DC}):

$$V_{DC} = I_{DC} R_L$$

$$= \frac{2I_m}{\pi} \cdot R_L$$

$$= \frac{2}{\pi}\left[\frac{V_m}{R_L+R_f}\right] R_L$$

$$= \frac{2V_m}{\pi}\left[\frac{1}{1+\frac{R_L}{R_f}}\right]$$

$$\boxed{V_{DC} = \frac{2V_m}{\pi}}$$

$$i = |I_m \sin\alpha|$$

$$i_{rms} = \sqrt{\frac{1}{T}\int_0^T i^2 \, d\alpha}$$

$$= \sqrt{\frac{1}{\pi}\int_0^\pi (i_m \sin\alpha)^2 \, d\alpha}$$

$$= \sqrt{\frac{1}{\pi}\int_0^\pi I_m^2 \sin\alpha \, d\alpha}$$

$$= I_m \sqrt{\frac{1}{\pi}\int_0^\pi \left(\frac{1-\cos 2\alpha}{2}\right) d\alpha}$$

$$= I_m \sqrt{\frac{1}{\pi}\left[\int_0^\pi \frac{1}{2} d\alpha - \int_0^\pi \frac{\cos 2\alpha}{2} d\alpha\right.}$$

$$= \sqrt{\frac{I_m^2}{\pi}\left(\frac{\pi}{2}\right)}$$

$$\boxed{i_{rms} = \frac{I_m}{\sqrt{2}}}$$

$$V_{rms} = I_{rms} R_L$$

$$= \frac{I_m}{\sqrt{2}} R_L$$

$$= \frac{1}{\sqrt{2}}\left(\frac{V_{rms}}{R_L + R_f}\right) R_L$$

$$\boxed{V_{rms} = \frac{V_m}{\sqrt{2}}}$$

$$P_{dc} = I_{dc} \times V_{dc}$$

$$= I_{dc} \times V_{dc} R_L$$

$$= I^2_{dc} R_L$$

$$\boxed{P_{dc} = \left(\frac{2I_m}{\pi}\right)^2 R_L}$$

$$P_{ac} = V_{rms} \cdot I_{rms}.$$

$$= I^2_{rms} \cdot R_L$$

$$\boxed{P_{ac} = \left(\frac{I_m}{\sqrt{2}}\right)^2 (R_f + R_L)}$$

Efficiency:

$$\%\eta = \frac{P_{ac}}{P_{dc}} = \frac{I^2_{dc} R_L}{I^2_{rms}(R_f + R_L)}$$

$$= \frac{\left(\frac{2 I_m}{\pi}\right)^2 R_L}{\left(\frac{I_m}{\sqrt{2}}\right)^2 (R_f + R_L)}$$

$$= \frac{4/\pi^2 R_L}{\frac{1}{2}(R_f + R_L)} = \frac{8}{\pi^2}\left[\frac{1}{1 + R_f/R_L}\right]$$

$$\boxed{\%\eta = 0.810 = 81\%}$$

Ripple Factor: It is the ratio of rms value of AC component present in the output to the DC component present in output

$$\boxed{r = \frac{I_{ac\,rms}}{I_{dc}}}$$

$i_{ac} = i.i_{dc}$

$$i_{ac\,rms} = \sqrt{\int_0^T \frac{1}{T} i^2_{ac}\, d\alpha}$$

$$= \sqrt{\frac{1}{T}\int_0^T (i - I_{DC})^2\, d\alpha}$$

$$= \sqrt{\frac{1}{T}\int_0^T (i^2 + I^2_{DC} - 2 i I_{DC})\, d\alpha}$$

$$= \sqrt{\frac{1}{T}\int_0^T i^2 d\alpha + \frac{1}{T}\int_0^T I_{DC}^2 d\alpha + \frac{1}{T}\int_0^T i I_{dc} d\alpha}$$

$$= \sqrt{I_{rms}^2 + I_{dc} + \frac{1}{T}\int_0^T d\alpha - 2I_{DC}\frac{1}{T}\int_0^T i\, d\alpha}$$

$$= \sqrt{I_{rms}^2 + I_{dc}^2 - 2I_{dc}^2}$$

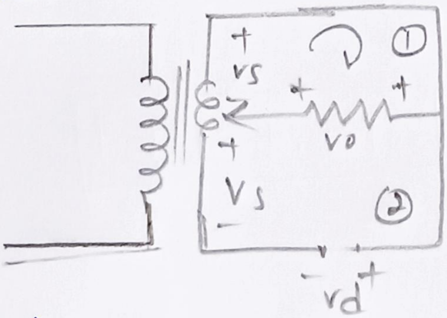
$$= \sqrt{I_{rms}^2 - I_{dc}^2}$$

$$= \sqrt{\frac{I_{rms}^2 - I_{dc}^2}{I_{dc}}}$$

$$= \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1} \quad = \sqrt{\left(\frac{I_m/\sqrt{2}}{\frac{2I_m}{\pi}}\right)^2 - 1}$$

$$\boxed{\gamma = 0.48}$$

Peak inverse voltage :-



It is defined as the maximum voltage across a biased diode in a rectifier

KVL ①

$-v_s + v_o = 0$ $\quad \boxed{v_o = v_s}$

KVL (2)

$-V_s + V_o + V_d = 0$

$V_d = 2V_s$

$\boxed{PIV = 2V_m}$

Transformer Utilization Factor :- (TUF)

$$TUF = \frac{\text{DC power developed to load } V_m}{\text{AC power ratio of transistor}}$$

$$= \frac{V_{DC} I_{DC}}{V_{rms} I_{rms}} = \frac{I_{DC}^2 R_L}{\frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}}}$$

$$= \frac{I_{DC}^2 R_L}{\frac{1}{2} I_m^2 (R_f + R_L)}$$

$$= \frac{(2 I_m / \pi)^2 R_L}{\frac{1}{2} I_m^2 (R_f + R_L)}$$

$$= \frac{8}{\pi} \left[\frac{1}{\frac{R_f}{R_L} + 1} \right]$$

$\boxed{TUF \cong 0.81}$

TUF of HWR is 0.282

FWR can be considered as 2HWR.

$TUF = 2(0.287) = 0.574.$

$$TUF = \frac{0.81 + 0.574}{2} = 0.692$$

$$\boxed{\therefore TUF = 0.692}$$

Form Factor:-

$$\text{Form Factor} = \frac{\text{rms value of o/p voltage}}{\text{Avg. value of o/p voltage}}$$

$$= \frac{V_m/\sqrt{2}}{\frac{1}{2}\frac{V_m}{\pi}} = \frac{V_m}{\sqrt{2}} \times \frac{\pi}{2V_m} = \frac{\pi}{2\sqrt{2}}$$

$$\boxed{\text{Form Factor} = 1.11}$$

Peak Factor:-

$$\text{Peak Factor} = \frac{\text{Peak value of o/p voltage}}{\text{rms value of o/p voltage}}$$

$$= \frac{V_m}{\frac{V_m}{\sqrt{2}}} = \sqrt{2}$$

$$\boxed{\text{Peak Factor} = \sqrt{2}}$$