Toppersnotes
Unleash the topper in you

UGC-NET

Paper - 2

NATIONAL TESTING AGENCY (NTA)

ELECTRONIC SCIENCE

Paper 2 – Volume 4

SIERRA
INNOVATIONS

Index

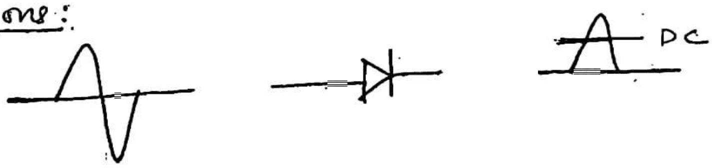
Unit – 4

Unit – 4

ANALOG ELECTRONICS.

Diodes: Applications:

(1). Rectifiers:



(2). Filter :

(3) Voltage Regulator :

} DC power supply

(4)*. Clippers
(5)*. Clampers
(6)* Peak detector
(7) Voltage Multiplier
(8) Diode as a digital logic gate. (AND gate & OR gate)
(9)* Diode is a analog gate (sampling gate)
(10). Diode as a varactor diode
(11)* Zener diode (Voltage Limiters)
(12). Diode Resistance
  (i) Static Resistance.
  *(ii) Dynamic Resistance :- small s/g analysis of a diode
(13). Diode capacitance
  (i) Transition capacitance (C_T)
  (ii) Diffusion capacitance (C_D)

BJT

(1). BJT device analysis
(2). BJT Biasing (DC)
(3). Small s/g Amplifiers (voltage amplifiers) ←
  Low freq. Analysis
  High freq. Analysis
  Frequency Response
(4). Large s/g Amplifiers (Power amplifiers)
(5). Feedback theory
Negative feedback theory (Amplifiers)

Positive feedback theory (oscillators)

Integrated theory (op Amps):

(1) Multistage Amplifiers
  (i) Effect of cascading on Bandwidth
  (ii) Important cascading designs
    (a). Cascode Amplifier (CE-CB)
      (OR)
      Wide Band amplifier
    (b) Darlington pair / high i/p impedence (CC-CC)

(2). Coupling Techniques
  (i) RC coupling
  (ii) Direct coupling

(3). Differential Amplifier

(4). Applications of OP-Amp

FET / MOSFET

(1) FET device
(2) FET Biasing
(3). FET Amplifiers.
} FET

MOSFET.

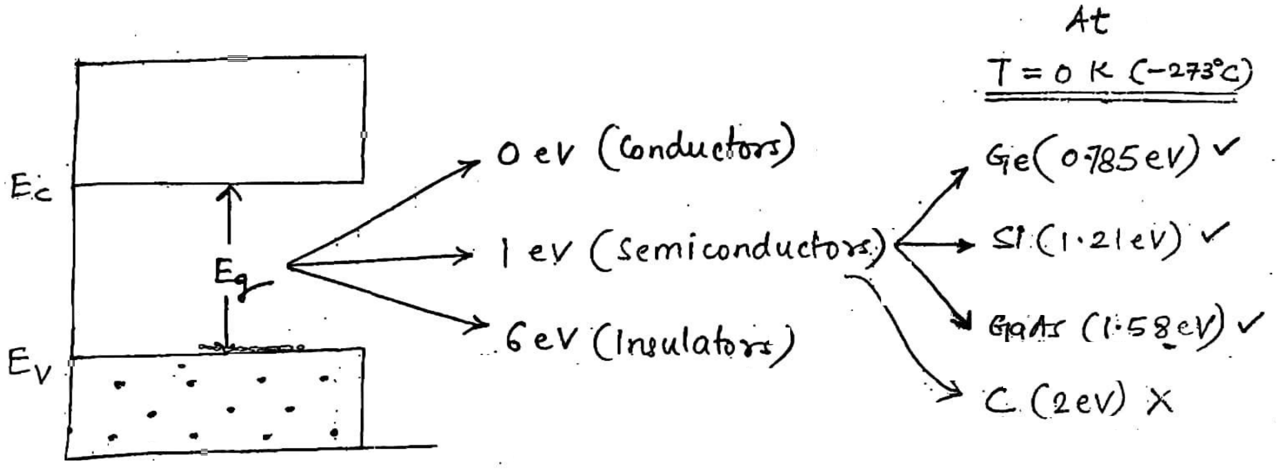
(1). MOSFET device

(2) MOSFET Biasing

(3). MOSFET Amplifiers

Introduction to Electronics:

Q. why 'Si' and 'Ge' are generally preferred compare to GaAs ?



At Room temperature 27°C (300 K) :

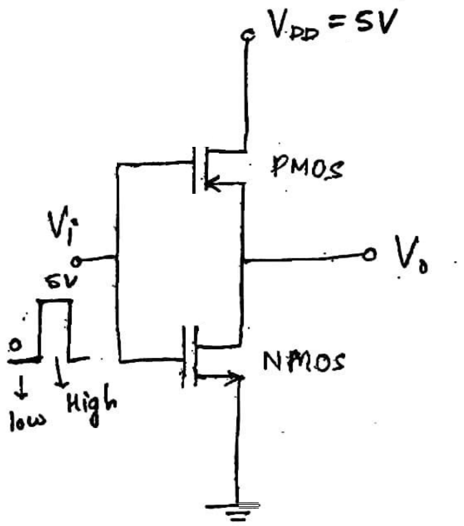
C is a bad semi-conductor.

A good semi-conductor must conduct at room temp..

A. The energy gap value of Si and Ge are less compared to GaAs, we expect more conduction in case of Si & Ge

Q. why GaAs is used in present CMOS Technology?

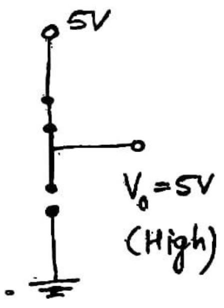
CMOS



$V_i = 0$ (Low)

PMOS → ON

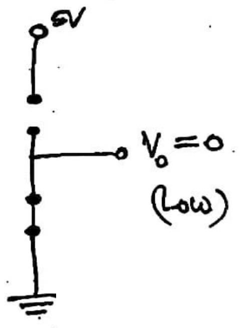
NMOS → OFF



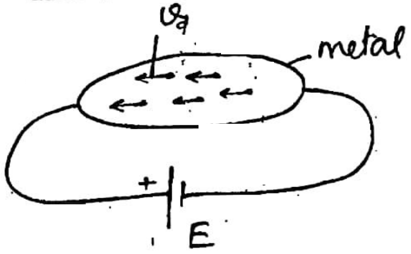
$V_i = 5V$ (High)

PMOS → OFF

NMOS → ON



Mobility



$V_d \propto E$

$v_d = \mu E$

Mobility, $\mu = \dfrac{\text{Drift velocity}}{\text{electric field}}$ $(m^2/V\,sec)$

Mobility of electron (μ_e) : (Room temp = 27°c)

μ_e (Si) = 1300 $cm^2/V\cdot sec$

μ_e (Ge) = 3,800 $cm^2/V\cdot sec$

μ_e (GaAs) = 8,500 $cm^2/V\cdot sec$ ✓ (High switching speed)

Temperature with standing capability

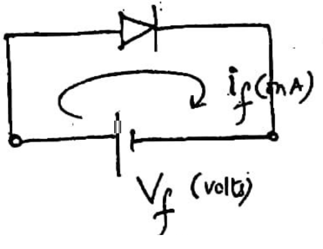
T (Ge) ≈ 100°C

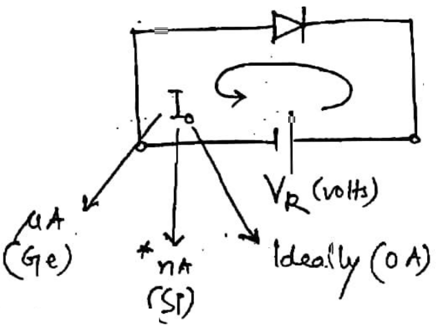
T (Si) ≈ 200°C

*T (GaAs) $\gtrsim$ 200°C

Q why 'Si' is more important than Ge ?

(1). $I_0 \rightarrow$ Reverse Saturation (or) Leakage current :





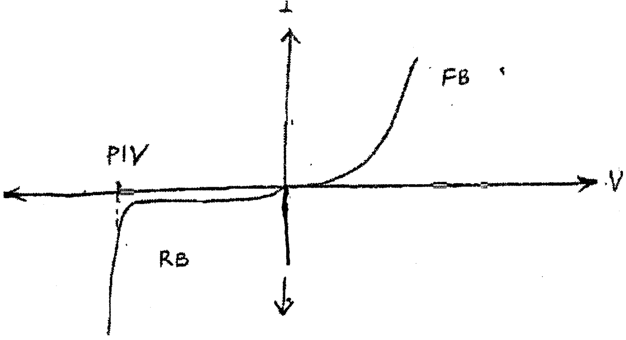
(2). Temperature with standing capability

Power dissipation (Heating effect)

T_{Ge} ≈ 100°c

* T_{Si} ≈ 200°c

(3). Peak Inverse Voltage (PIV):



*PIV (Si) ≈ 1000 V

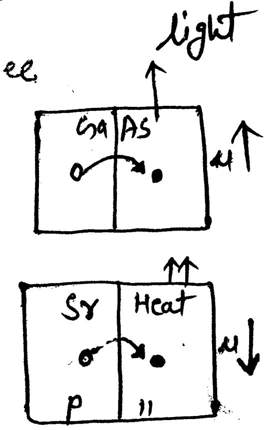
PIV (Ge) ≈ 400 V

Q. Give the important properties of GaAs ?

(1) At high frequency applications GaAs is used (mobility of GaAs is more)

(2) μ_e (GaAs) → 8,500 $cm^2/V\text{-sec}$

μ_h (GaAs) → 400 $cm^2/V\text{-sec}$



for Si

μ_e (Si) → 1300 $cm^2/V\text{-sec}$

μ_h (Si) → 500 $cm^2/V\text{-sec}$

for Ge

μ_e (Ge) → 3,800 $cm^2/V\text{-sec}$

μ_h (Ge) → 1,800 $cm^2/V\text{-sec}$

(3). GaAs is a best example for direct band gap.

Si & Ge are best examples for indirect band gap.

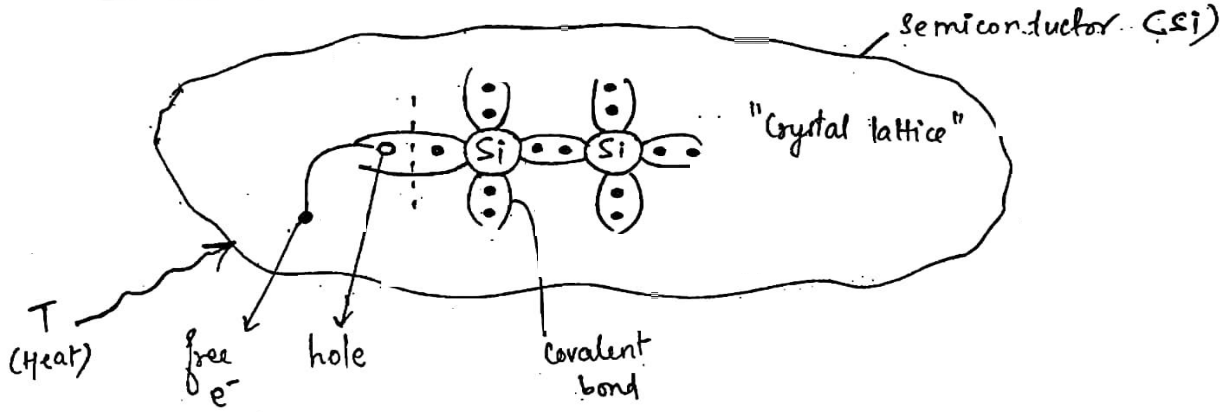
(4). GaAs is a compound semiconductor

$$\underbrace{\overset{\text{Ga}}{\text{III group}} \quad + \quad \overset{\text{As}}{\text{V group}}}_{\text{IV group}}$$

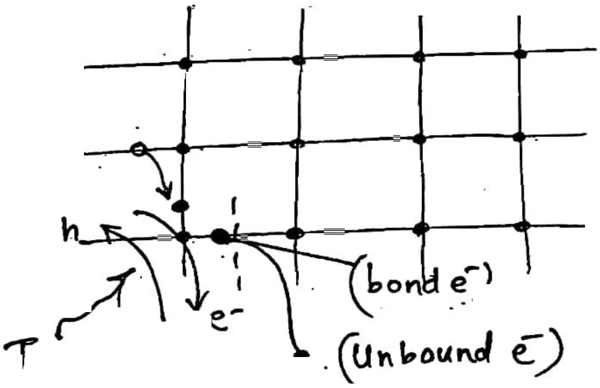
(5). GaAs is used in optics.

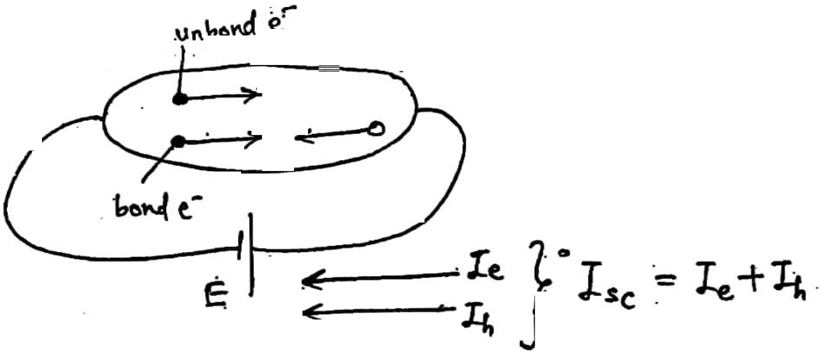
Q. why mobility of e^- > mobility of holes . ?

Hole concept :



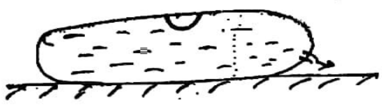
Crystal Lattice

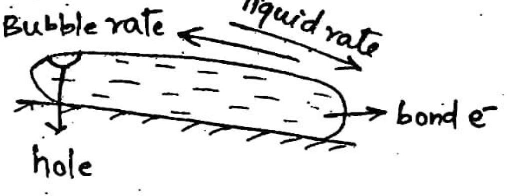




$I_{sc} = I_e + I_h$

Eg: Glass-Bubble → Liquid rate is not easy to analyse, so bubble rate (hole) is easy to analyse the liquid rate (bond $\bar{e}$)





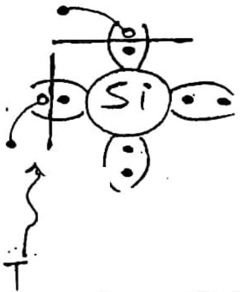
The mobility of an unbond e^- (free e^-) is always greater than bond e^- (valence electrons)

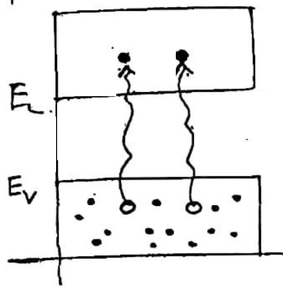
Q. Give the classification of semiconductor :

Semiconductor

Intrinsic sc (pure)

Extrinsic sc (Impure)





Intrinsic sc + other material ⇒ Extrinsic sc

Pentavalent impurity (Eg Arsenic, Antimony Bismuth, phosphorus etc)

Trivalent impurity (Eg gallium, Indium, Boron, Aluminium etc)

$n \rightarrow$ concentration of e^-/cm^3

$p \rightarrow$ conc. of holes $/cm^3$

$n_i \rightarrow$ Inrinsic conc. (e-h) $/cm^3$.

$n_i = p = n$

$n_i \propto$ temp

Si :.

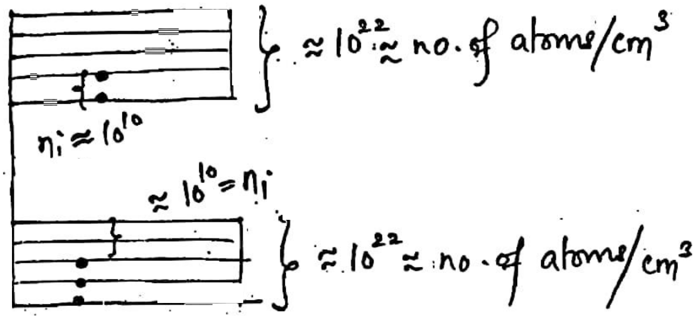
n_i (300 K) $\rightarrow 1.5 \times 10^{10}/cm^3$

No. of atoms $/cm^3 \rightarrow 5.0 \times 10^{22}/cm^3$

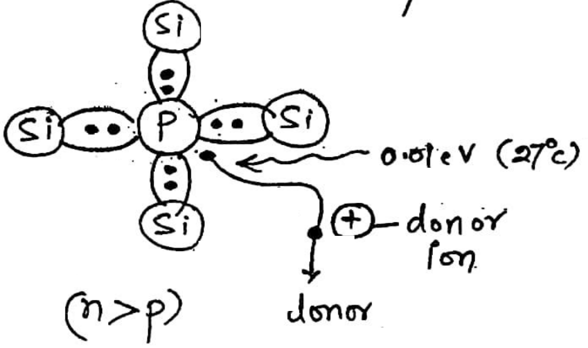
Ge :

n_i (300 K) $\rightarrow 2.5 \times 10^{13}/cm^3$. ($E_g \downarrow$)

No. of atoms$/cm^3 \rightarrow 4.4 \times 10^{22}/cm^3$ (size of Ge $\uparrow$)

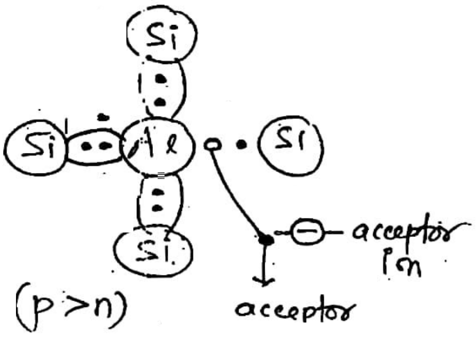


Pentavalent Impurity:



Majority carriers → Electrons
Minority carriers → holes
N-type Semi-conductor

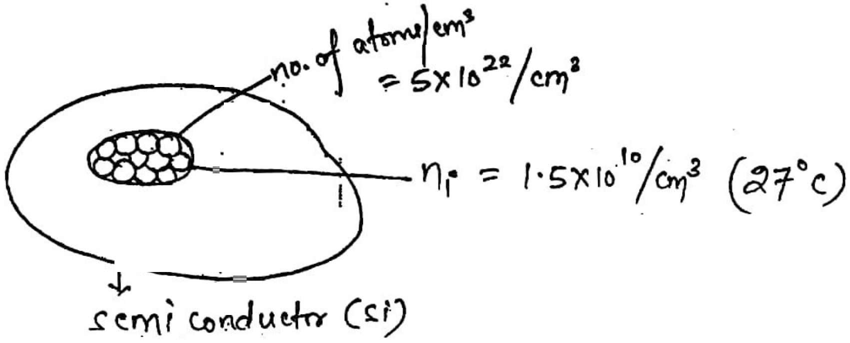
Trivalent Impurity:



Majority carriers → Holes
Minority carriers → Electrons
P-type semi-conductor

* that's why N-type device is always preferred to P-type because electron mobility is higher than hole mobility

Q. Explain about Doping concept in semi conductors?



Doping: N_D → Donor atoms/cm^3

(1). **Ordinary p-n diodes:**

10^8 sc atoms → 1 impurity [1 'p' (pentavalent)]

5×10^{22} sc atoms → N_D

$N_D = \frac{5\times10^{22}}{10^8} = 5\times10^{14}/cm^3$

$N_D > N_i$

(2). **Zener Diode:**

10^6 s.c atoms → 1 impurity {1 'p'}

5×10^{22} s.c atoms → N_D

$N_D = \frac{5\times10^{22}}{10^6} = 5\times10^{16}/cm^3$

$N_D >> N_i$

(3) **Tunnel diode:**

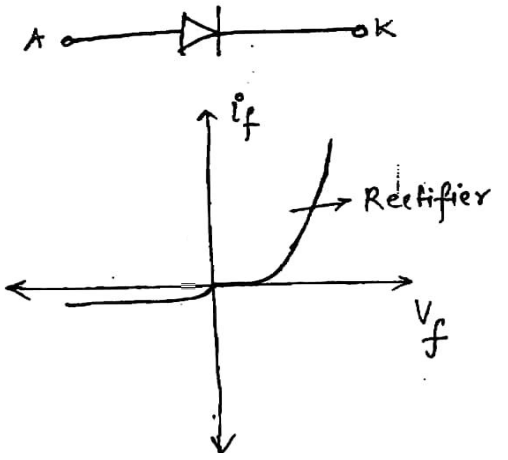
10^3 s.c atoms → 1 impurity

5×10^{22} s.c. atoms → N_D.

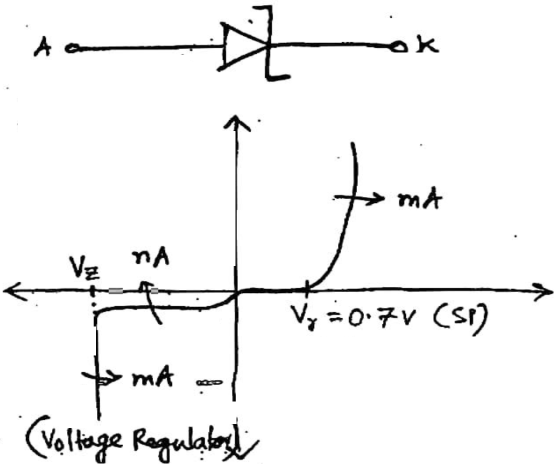
$N_D = \frac{5\times10^{22}}{10^3} = 5\times10^{19}/cm^3$

$N_D >>> N_i$

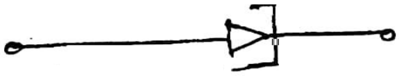
Ordinary p-n diode:

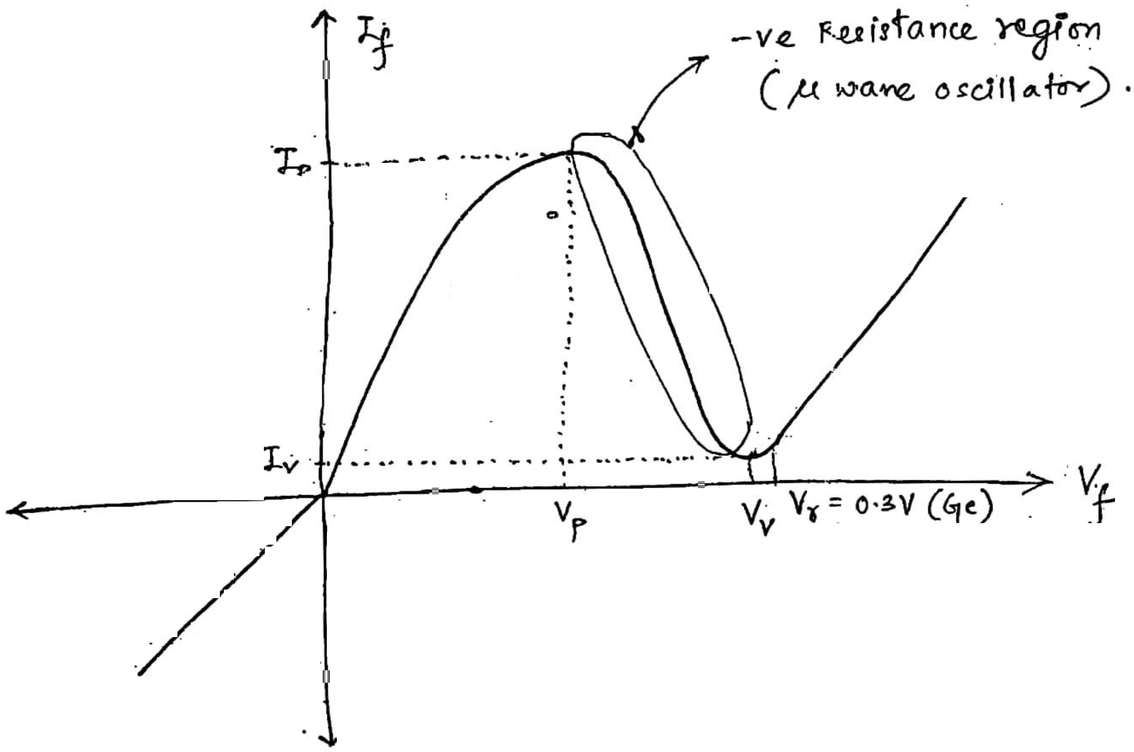


Zener Diode:



Tunnel diode :



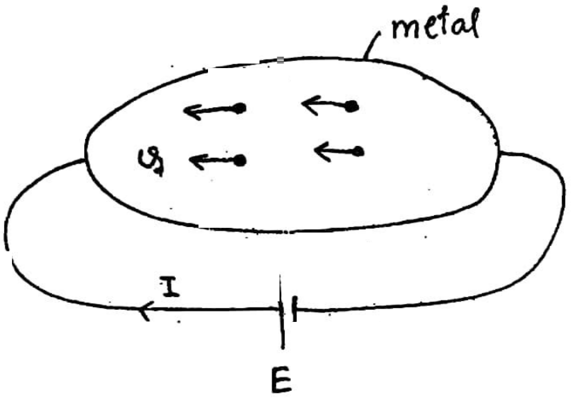


$$R = \frac{dV}{dI} = \frac{V_v - V_p}{I_v - I_p} = \ldots -ve.$$

Q Explain about drift current in semiconductors ?

Drift current

Drift → movement
(greek word)



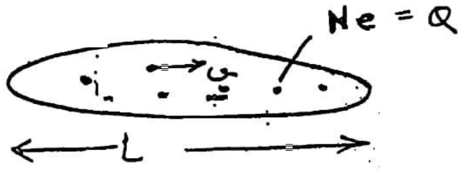
$v_d \propto E$
$v_d = \mu E$
$\mu = \frac{v_d}{E}$ $m^2/V\text{-sec}$

1). "The current is produced due to the drifting of free electrons is called as Drift current".

(2). The current can occur in metals & semi-conductors.

(3). Drift current mechanism can also be called as "potential gradient"

Current Density : (J)



$J = \frac{I}{A}$ A/m^2

$I = \frac{Ne}{t}$

$I = \frac{Ne\,v_d}{L}$

$J = \frac{Ne\,v_d}{AL}$ $\quad (\because n = N/AL)$

$\boxed{J = n e v_d}$ $\quad (\because \rho \rightarrow$ charge density)
$\rho = ne$

$J = \rho v$

Metals :

$J = ne\mu E$ $\quad (\because v_d = \mu E)$

$J = \sigma E$ $\quad (\because \sigma = ne\mu)$

Semi-conductors :

$J_{sc} = J_n + J_p$

$J_n = nq\mu_n E$

$J_p = pq\mu_p E$

$$J_{sc} = \underbrace{(n\mu_n + p\mu_p)\cdot q}_{\sigma_{s.c}} E$$

$\therefore \sigma_{s.c} = (n\mu_n + p\mu_p) q$

(a) **Intrinsic s.c** – $(n = p = n_i)$

$$\sigma_{intrinsic} = n_i(\mu_n + \mu_p)q$$

(a) **Extrinsic s.c** – $(n \neq p)$

(i) · **N-type** : $(n > p)$

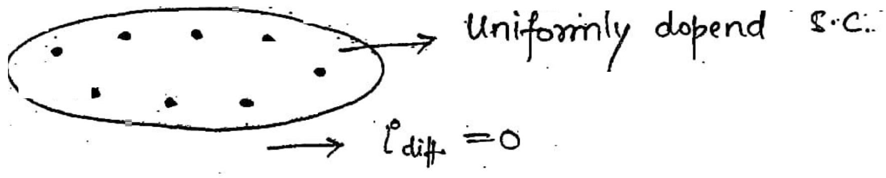
$$\sigma_{N\text{-}type} = nq\mu_n$$
$$\approx N_D q \mu_n$$

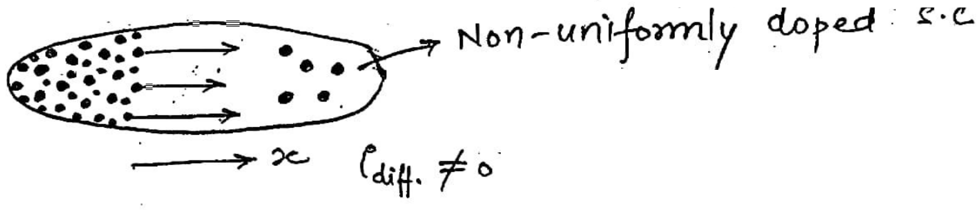
(ii) · **P-type** : $(p > n)$

$$\sigma_{p\text{-}type} = pq\mu_p$$
$$\approx N_A q \mu_p$$

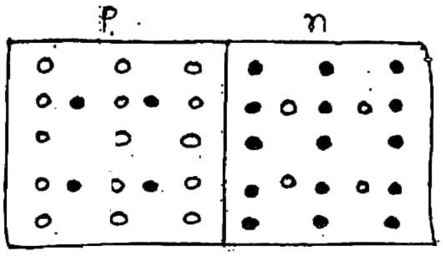
Q. Explain about Diffusion current in semi-conductors?

Diffusion current :





Eg



pn jxn is a best example for non-uni-formly doped s.c.

$$J_n \propto q \frac{dn}{dx}$$

$$J_n = D_n q \frac{dn}{dx}$$ ($D_n \rightarrow$ Diffusion constant for e^-)

$$I_n = A q D_n \frac{dn}{dx}$$

$$J_p \propto q \frac{dp}{dx}$$

$$J_p = -D_p q \frac{dp}{dx}$$ ($D_p \rightarrow$ Diffusion constant for holes)

$$I_p = -A q D_p \frac{dp}{dx}$$

Diffusion current – The rate of change of concentration w.r to distance x is called as diffusion current.

Diffusion current mechanism can also be called as "concentration gradient

Analysis:

According to kinetic gas theory –

$$D \propto \mu \Rightarrow \frac{D}{\mu} = V_T = \text{constant}$$

$$D = \mu V_T$$

$V_T \Rightarrow$ Volt equivalent temp. (or) thermal voltage

$V_T = \frac{KT}{q}$ where $K \rightarrow$ Boltzman constant
$T \rightarrow$ Temperature

In semi-conductors:

$$\frac{D_n}{\mu_n} = \frac{D_p}{\mu_p} = V_T$$ —— Einstein Relation

$$V_T = \frac{KT}{q}$$

$$= \frac{T}{q/K}$$

As $q = e^- = 1.6 \times 10^{-19}\ C$

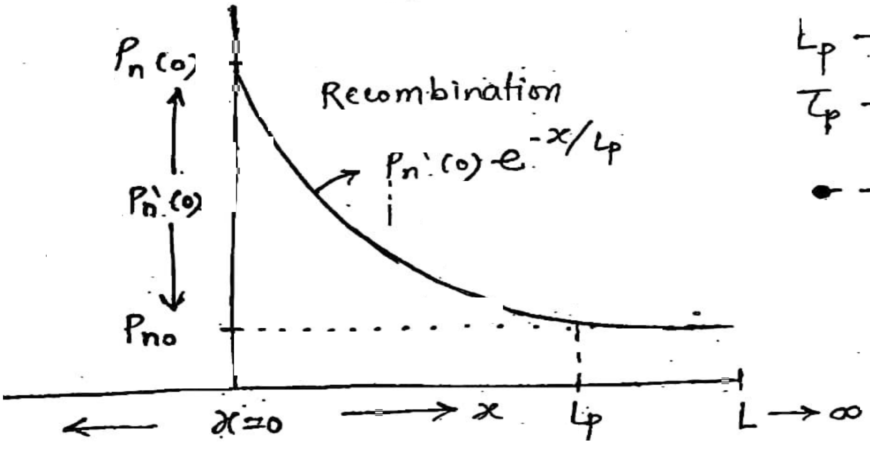
$K = 1.38 \times 10^{-23}\ J/K$

$$V_T = \frac{T(K)}{11{,}600}\ \text{volts}$$

Q.- Calculate volt equivalent Temp at room temp.?

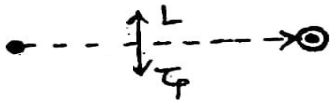
A. $V_T = \frac{300}{11600} = 25.86\ mV \approx 26\ mV\ /(25\ mV)$

Graphical Analysis:



$L_p \to$ Diffusion length

$\tau_p \to$ Carrier life time



$$L_p^2 = D_p \tau_p$$

$$\text{Diffusion rate} \propto \frac{1}{\text{Recombination rate}}$$

Case -(1)

$x = 0$

$P = P_n(0) \cdot e^{-0/L_p}$

$= P_n'(0) \cdot (1)$

$= P_n'(0)$

Case -(2)

$x = L_p$

$P = P_n'(0) \cdot e^{-L_p/L_p}$

$= P_n'(0) \cdot \frac{1}{e}$

$= \frac{1}{e} \cdot P_n'(0)$

Case -(3)

$x = \infty$

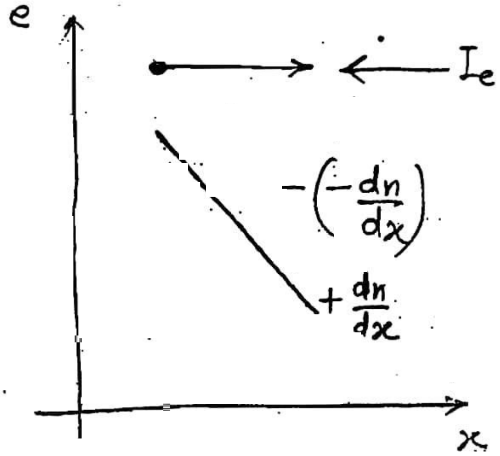
$\therefore P = P_n'(0) \cdot e^{-\infty/L_p}$

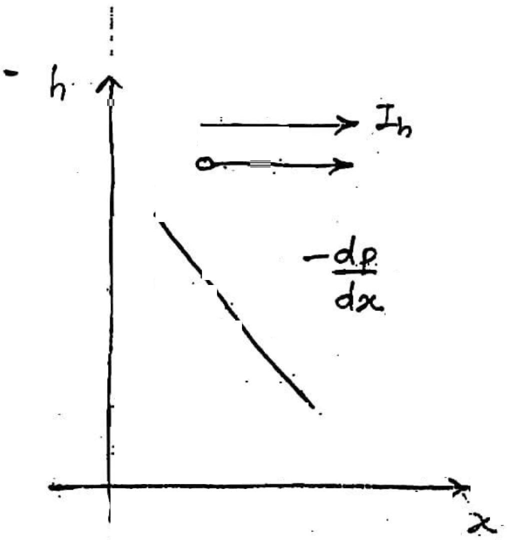
$= P_n'(0) \cdot \frac{1}{e^\infty}$

$= 0$

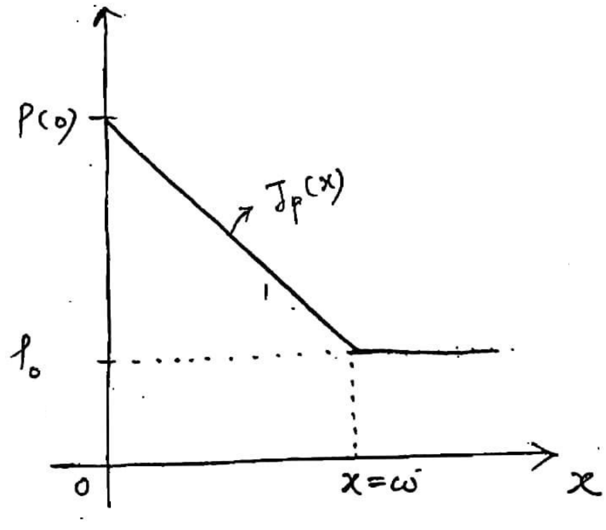
(1). When the thickness of material is more, recombination rate will be more, diffusion rate will be less
(Non-linear graph)

(2). When the thickness of material is very less, diffusion rate will increase but recombination rate will decrease
(Graph is linear)





Problems in diffusion current :



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

$$= -q D_p \frac{P(0) - P_0}{0 - w}$$

$$= \frac{q D_p [P(0) - P_0]}{w}$$

$\longrightarrow$
$\longrightarrow I_h$ } +ve