EI-27003: Electronics Devices and Circuits
Lecture - 4

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LECTURE - 4

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Current Conduction In Semiconductor

- Let us consider current conduction in metal

Let E= Applied electric field

F= Force experienced by e due to electric field

a= Acceleration

t= time between collisions

v= drift velocity

q= charge of electron

m= mass of electron

- Force experienced by e due to electric field: F=q.E

Acceleration a=Force/Mass = $\frac{F}{m}$ or a=$\frac{q.E}{m}$

Drift velocity= v=a.t = $\frac{q.E}{m}$.t or v = μ.E ------eq(1)

Current conduction….

- Where $\mu=\frac{qt}{m}$ is called as Mobility of Electron.

Mobility has units of m^2/Volt-sec.

Now consider metallic bar as shown in fig.

Average velocity of electrons=$\frac{L}{T}$

No of electrons passing through any area per second=$\frac{N}{T}$

Total charge passing through any area per second = q. $\frac{N}{T}$

------ eq. (2)

Current conduction….

- Multiplying and dividing eq.(2) by L

$$I = q.\frac{N}{T}\frac{L}{L} = \frac{qN}{L}\frac{L}{T} \quad \text{but} \quad v = \frac{L}{T}$$

$$I = \frac{qNV}{L}$$

Now current density: $J = \frac{I}{A} = \frac{qNV}{LA}$ but $\frac{N}{LA}$ = n, concentration

Hence: $J = qnv$ but again $v = \mu.E$

$J = qn\mu E$ but $\sigma = qn\mu$ is called conductivity

$J = \sigma E$

Since in conductor, current flows because of only electrons and is proportional to electric field (potential).

By same logic we can develop current equation for Semiconductors.

Current in Semiconductor

- Current which flows because of electric field is Dirft current.
- In semiconductor current flows because of both electrons and holes.
- Hence for p-type semiconductor: $J_p=q\mu_p pE$

- For n-type semiconductor: $J_n=q\mu_n nE$

➢ Where

J= current density

q= charge

μ= mobility

E= Electric field

n / p= concentration of electrons/hole

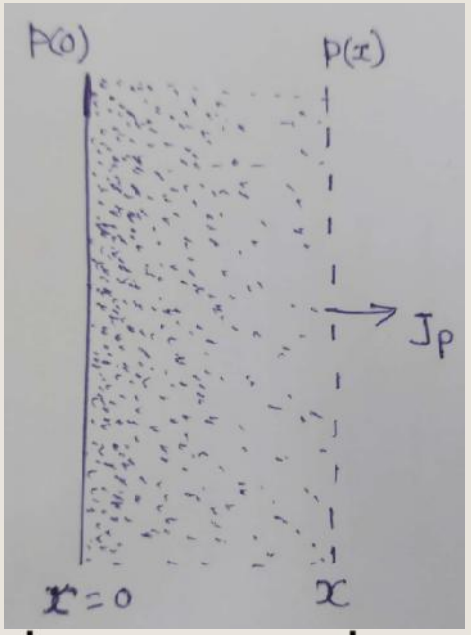
Current in Semiconductor

- Current in semiconductor flows because of:
  - (i) Drift current – due to potential gradient
  - (ii) Diffusion current – due to concentration gradient

- Diffusion Process: When a bottle of perfume is opened in one corner of a closed room, the scent is soon detected throughout the room.
- If there is no convection or other net motion of the air, the scent spreads by diffusion.
- Diffusion is the natural result of the random motion of the individual molecules.

Diffusion current

- Now consider p-type semiconductor, at x=0, concentration of holes is p(0) as these holes travels randomly, then at x, concentration of holes be p(x).
- Certainly concentration of holes decreases from x=0 to X=x.



- These concentration of holes which are charge carriers constitute a current, called as diffusion current.
- Hence current density Jp will be proportional to concentration of holes will also goes on decreasing as it approaches x.
- So $J_p=-qD_p\frac{dp}{dx}$ Similarly for n-type semiconductor

$$J_n= qD_n\frac{dn}{dx}$$

Drift and Diffusion Current

- It is possible to have both potential gradient and concentration gradient simultaneously within a semiconductor.
- Hence total current is sum of drift current and diffusion current.

➢ $J_p = q\mu_p pE - qD_p \frac{dp}{dx}$ for p-type

➢ $J_n = q\mu_n nE + qD_n \frac{dn}{dx}$ for n-type

Quiz

- https://forms.gle/1JKSm3QT1kPG1hdA7