* Current Transport by Diffusion

* pn junction
  - Applications
  - Basic structure
  - Behaviour in Equilibrium

$J_{drift} = (\mu_n n + \mu_p p) E q$

$np = n_i^2$

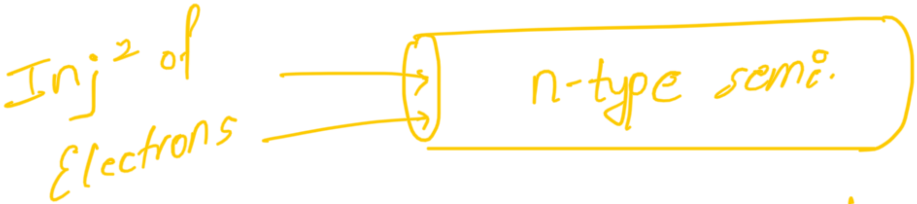
Drift → electric field is required

Diffusion : voltage/ $\vec{E}$ not required.

* Diffusion

→ it's like ink molecules in water.

→ movement of charge carriers from a region of high concentration to a region of lower concentration.



gradient or slope = 0 , no diffusion.

$J \propto \frac{dn}{dx}$ → slope of concentration

distance

$dx \rightarrow$ distance

$$\underbrace{J}_{\text{current density}} = \underbrace{D_n}_{\text{Diffusivity}} \frac{dn}{dx} \, q$$

In general both e^- concentⁿ gradient & hole " " .

$$J_{total} = \left(\underbrace{D_n}_{34\ cm^2/sec} \frac{dn}{dx} - \underbrace{D_p}_{12\ cm^2/sec} \frac{dP}{dx} \right) q$$

Example:

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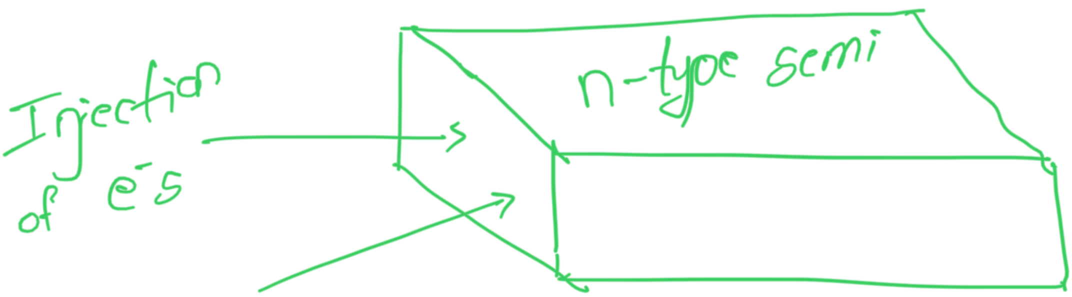
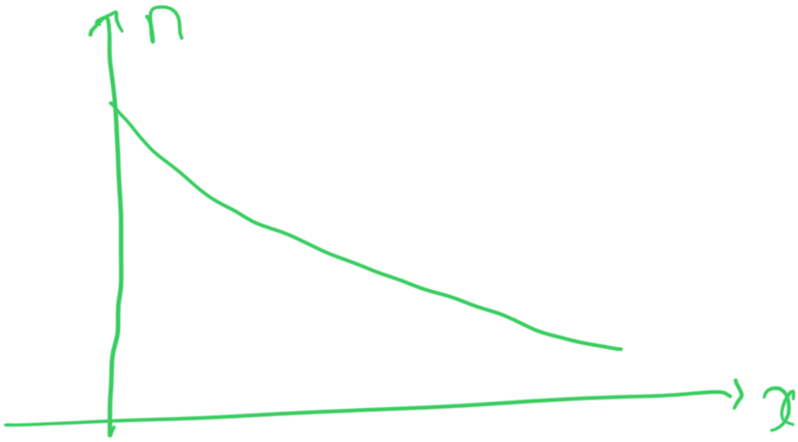
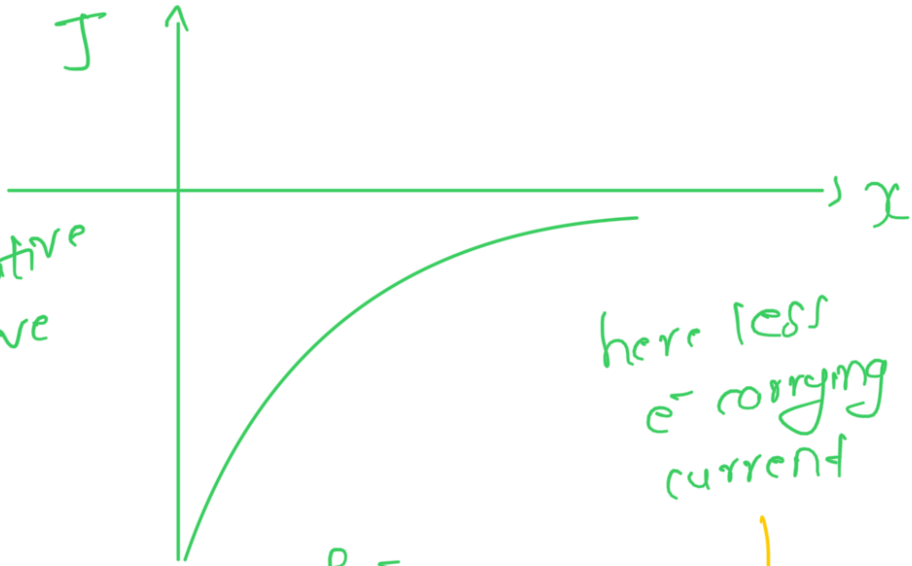






Since derivative is negative

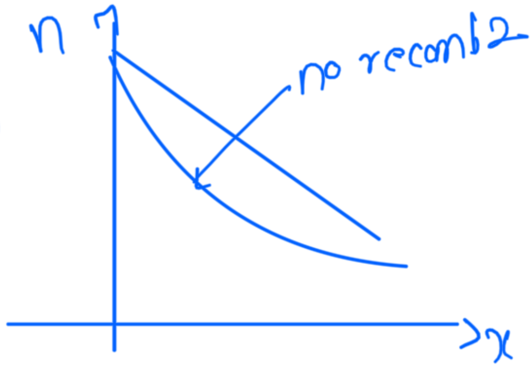
here less e^- carrying current

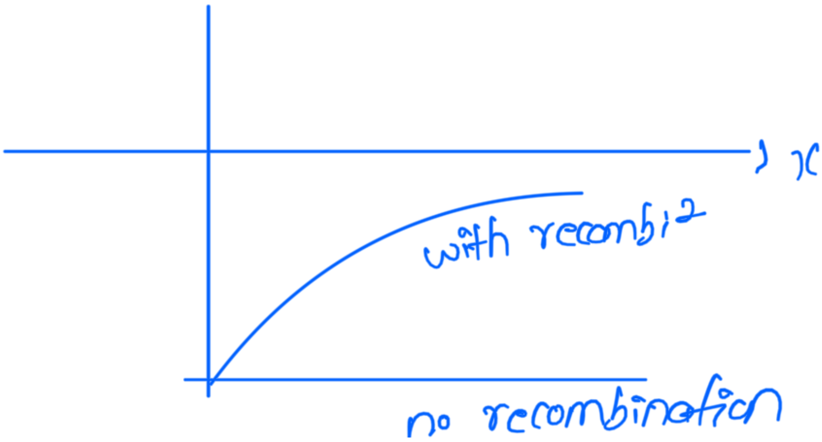
lots of e^- here carrying current

Why amount of current is less?

Injected e^- recombine with holes in the semiconductor.

* if: no. of holes is small, i.e donor atoms (Phosphrous)





Einstein's Relation:

$$\frac{D}{\mu} = \frac{kT}{q}$$

1.38×10^{-23}

$T = 300$

26 mV @ T = 300 K.

Thermal Voltage

$\mu \rightarrow$ mobility

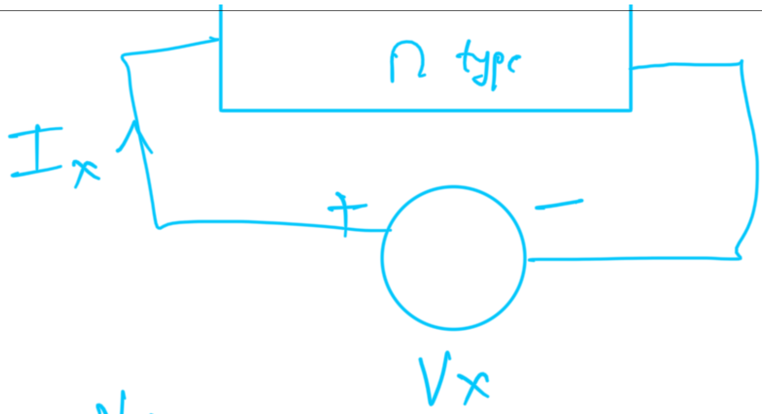
$D \rightarrow$ diffusibility

* The P-N Junction

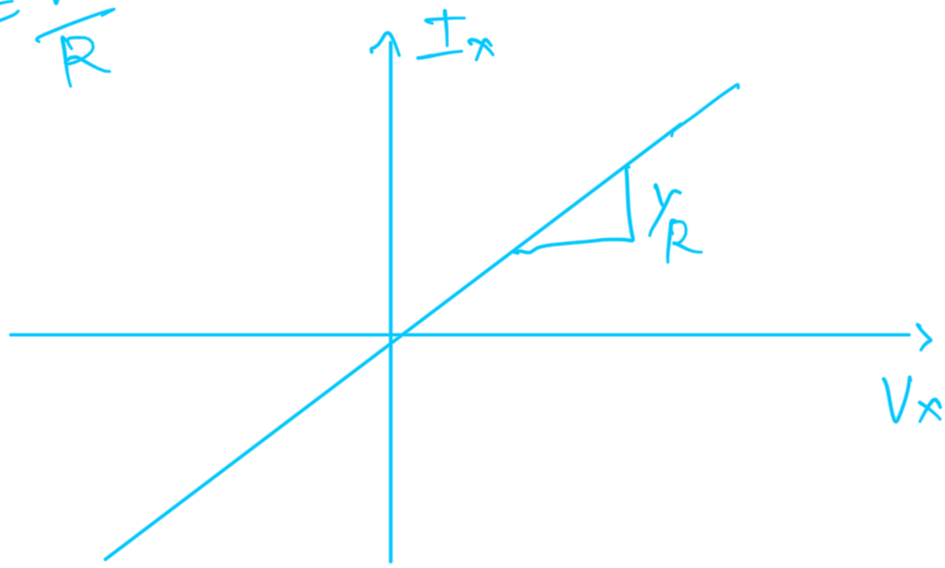
Applications:

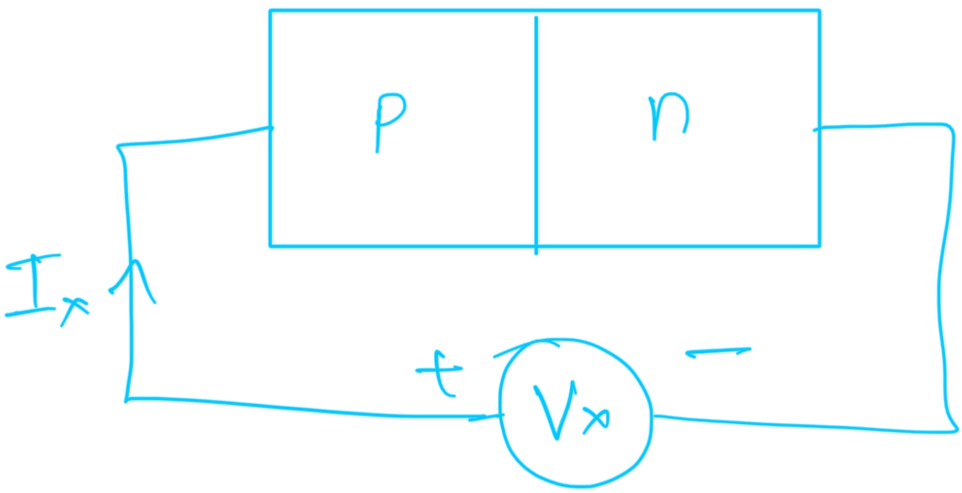
- Chargers and Adapters (Diode)
- Voltage multipliers

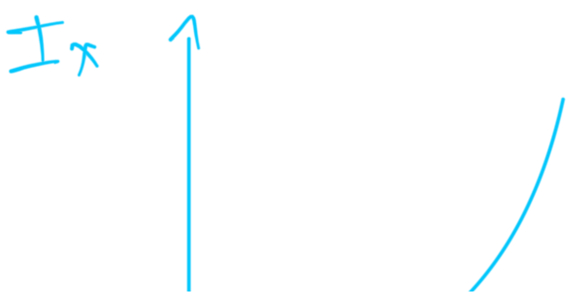
Quick experiment:

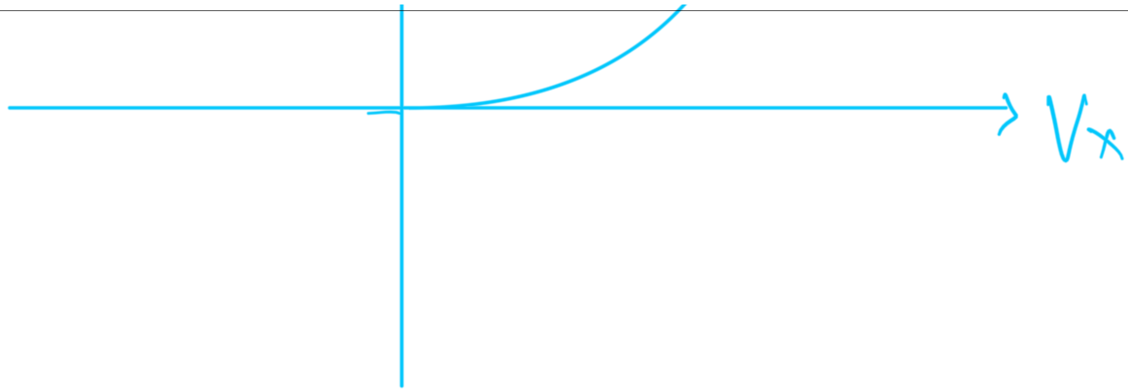


$$I_x = \frac{V_x}{R}$$









PN junction not satisfy Ohm's law.

Difference is :

1. It has different behaviour for +ve & −ve voltage
2. When V is +ve, it's an exponential f^n.

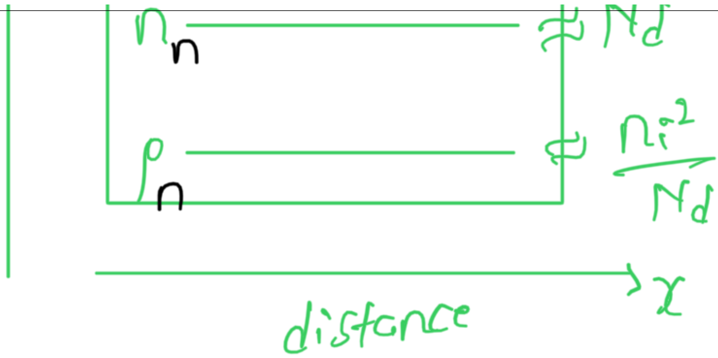
Two Questions:

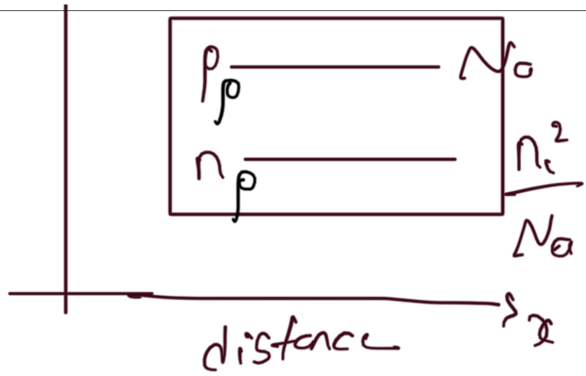
① How do charge carriers redistribute themselves after the pn-junction is formed?

② How does the PN junction behave under

- Equilibrium
- Reverse bias
- Forward bias

Some Observations:





(subscript)

if we simply attach p & n, it will not form p-n junction.

In order to create p-n junction, it have to be <u>single</u> <u>crystal</u>

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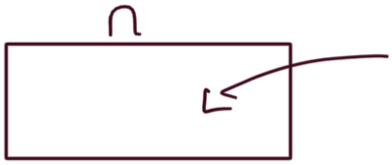

What is the net charge in this device?

<u>charge</u> <u>neutrality</u> ∵ every e^- has 1 counterpart 'proton' in the nucleus of the atom

net charge = 0

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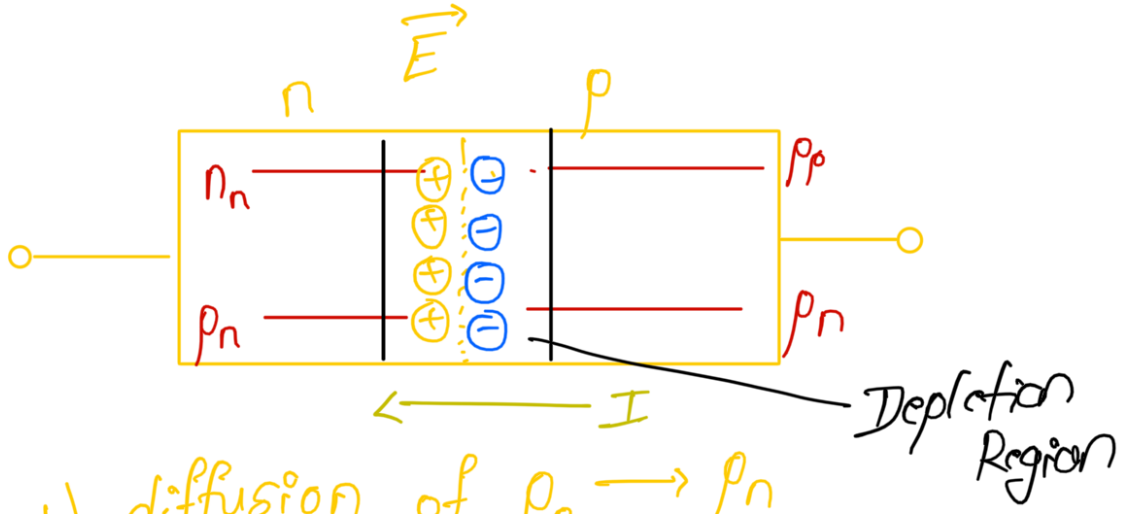
If an e^- is taken out of the device, then we have net positive charge i.e positive ion is formed.

* pn Junction in Equilibrium



1} diffusion of $p_p \longrightarrow p_n$

i.e holes diffusion from high conc. to lower conc.

2} diffusion of $n_n \longrightarrow p_n$

i.e e^- diffusion from high conc. to lower conc.

But we haven't connected anything to the terminal. How current 'I' flow occurs? How long will it exists?

Electric field gets created at the interface b/w +ve & -ve ions

ions form space-charge $\Rightarrow \vec{E}$

thus created Electric field opposes

diffusion of e & hole

i.e junction reached equilibrium.