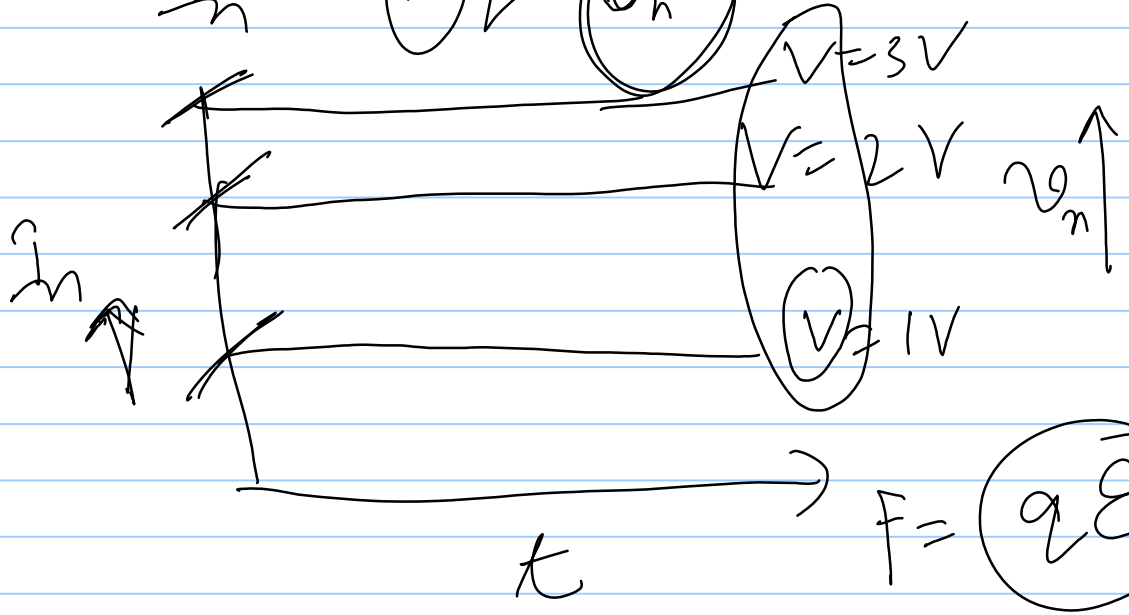
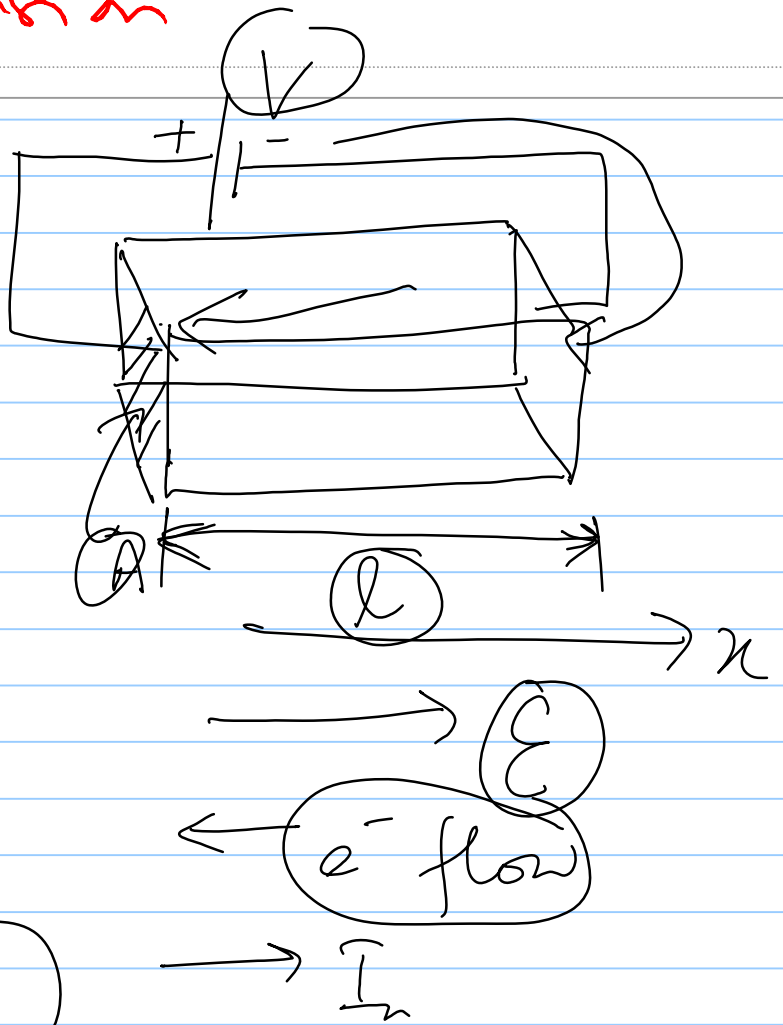
Carrier Drift and Diffusion

$$I_n = A(-q)(n)(-v_n)$$

$$I_n = Aqnv_n$$





$v_n \propto \mathcal{E}$

$v_n = \mu_n \mathcal{E}$

μ_n → mobility of electron

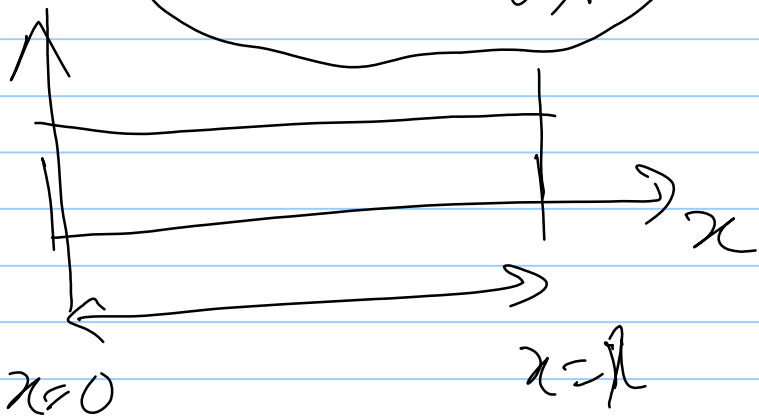
Collision

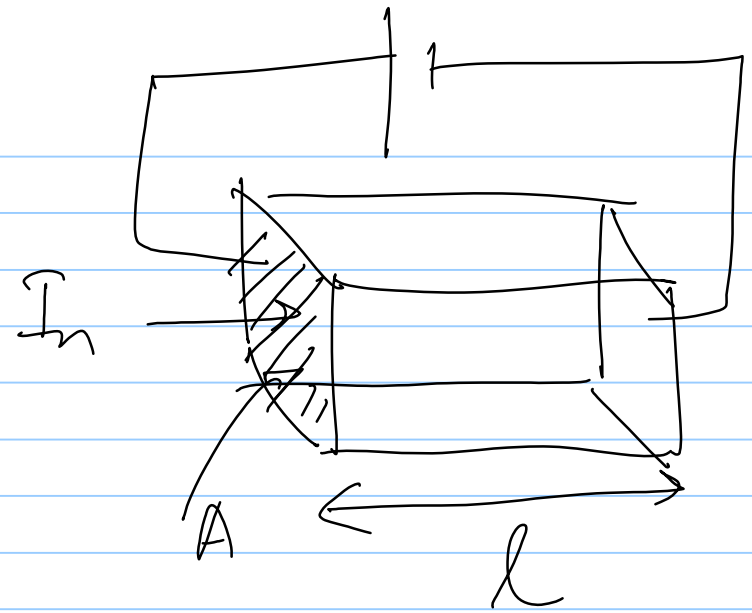
$\mu_n \rightarrow \frac{cm}{Sec\text{-}V} \frac{cm}{} = \left[\frac{cm^2}{V\text{-}Sec}\right]$

v_n → drift velocity

$|\mathcal{E}| = \left|\frac{V}{l}\right|$

$\mathcal{E}(x) = -\frac{dV}{dx}$





$$I_n = A n q v_n$$
$$= A n q \mu_n \mathcal{E}$$
$$= A n q \mu_n \frac{V}{\ell}$$

$$R = \frac{V}{I_n} = \frac{\ell}{A} \cdot \left(\frac{1}{n q \mu_n} \right) = \rho \left(\frac{\ell}{A} \right) \Rightarrow \rho = \frac{1}{n q \mu_n}$$

n-type Semiconductor bar

ρ = Resistivity $(\Omega\text{-cm}) = \frac{1}{n q \mu_n}$

Conductivity $\sigma_n = \frac{1}{\rho_n} = n q \mu_n$

$I_p = A p q \mu_p \mathcal{E} = A p q v_p$

μ_p: hole mobility

v_p: hole drift velocity

p-type

$R = \frac{V}{I_p} = \frac{l}{A} \times \frac{1}{p q \mu_p} = \frac{\rho \cdot l}{A} \Rightarrow \rho = \frac{1}{p q \mu_p}$

$$I = I_p + I_n = Aq\left(n v_n + p v_p\right)$$

$$= Aq\mathcal{E}\left(n\mu_n + p\mu_p\right)$$

$$R = \frac{V}{I} = \frac{\ell}{A}\cdot\frac{1}{pq\mu_p + nq\mu_n} = \frac{\ell}{A}\cdot\rho$$

$$\rho = \frac{1}{pq\mu_p + nq\mu_n} \Rightarrow \boxed{\sigma = pq\mu_p + nq\mu_n}$$

μ_p in $Si = 480\ cm^2/V\text{-}s$

μ_n in $Si = 1250\ cm^2/V\text{-}s$

Diffusion

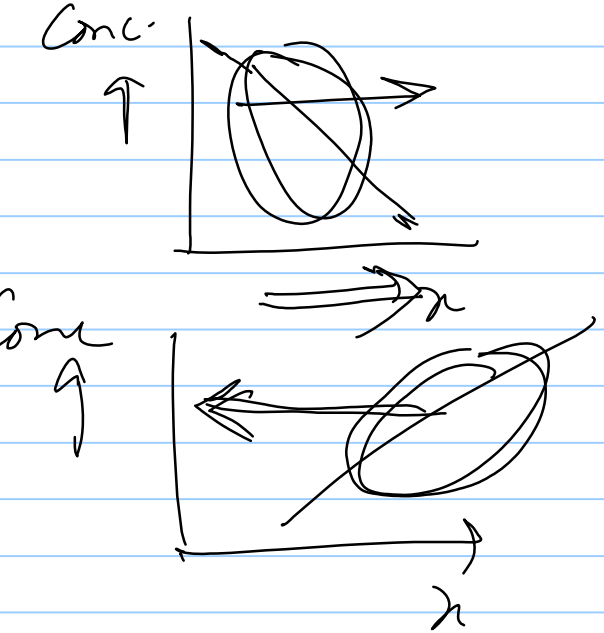
↓

can occur in gas molecules (neutral)

Particle/sec $\propto -\frac{d(\text{concentration})}{dx}$

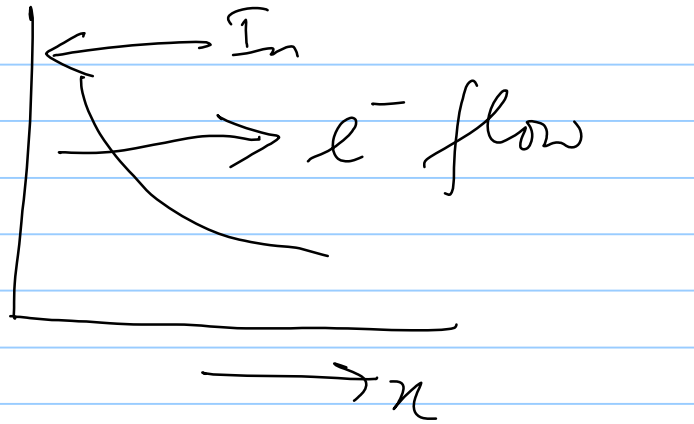
$$\text{Particle current} = -D A \frac{d}{dx}(\text{conc.})$$

Diffusion const. (Diffusivity)



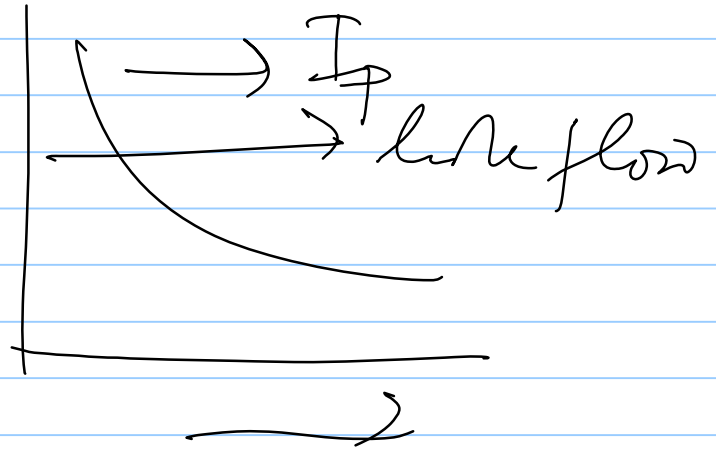
$$I_{n,\text{diffusion}} = (-q)\left(-D_n A \frac{dn}{dx}\right)$$

$$\Rightarrow A q D_n \frac{dn}{dx}$$



$$I_{p,\text{diffusion}} = q\left(-D_p A \frac{dp}{dx}\right)$$

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



$$\vec{I}_n = A n q \mu_n \mathcal{E} + A q D_n \frac{dn}{dx}$$

$$I_p = A p q \mu_p \mathcal{E} - A q D_p \frac{dp}{dx}$$

Drift – Diffusion Relation of electron and hole currents

$\mu, D \rightarrow$ options of collision forces inside the semiconductor

Einstein's Rel^n

$$D_n \propto \mu_n$$

$$D_p \propto \mu_p$$

$$\frac{D_n}{\mu} = \text{Const} = \frac{D_p}{\mu_p}$$

T

$$\frac{D_n}{\mu_n} = \frac{D_p}{\mu_p} = \frac{kT}{q} = V_T \quad \text{(thermal voltage)}$$

$$V_T \text{ (At } T = 300K) = 0.0259V$$