* Doping : n type and p-type Semiconductors
  - Modified carrier density

* Moment of charge (Carrier transport)
  - Drift
  - Diffusion

Doping

If we add N donor atoms, then density of free electrons $= N_d \ /cm^3$

n : density of free electrons
p : density of holes

For pure silicon : $n = p = n_i \implies n.p = n_i^2$

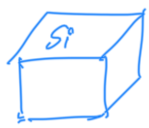
For doped silicon : $n.p = n_i^2$

For n-type Si : $n \approx N_d$

$$p \approx \frac{n_i^2}{N_d}$$

Example:

Add 10^{15} phosphrous atoms



$\implies n \approx 10^{15} = N_d \quad /cm^3$

$$p = \frac{n_i^2}{n} \approx \frac{n_i^2}{N_d} = \frac{10^{20}}{10^{15}} = 10^5 \ /cm^3$$

majority carrier

minority carrier

Can holes become majority carriers ?

```
      Si
      | o      → hole
 = Si = B = Si
   ||   ||
        Si
```

p-type Semi-conductor

If we add N_a boron atoms per cm^3
N_a → acceptor

$\Rightarrow$ N_a holes

$$p \cong N_a$$

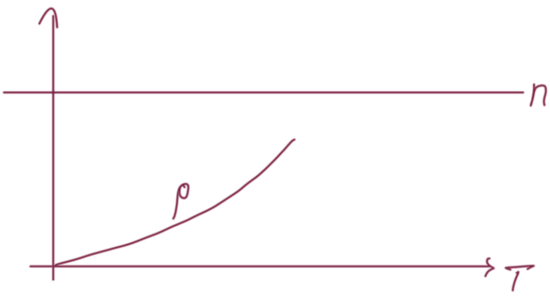
$$np = n_i^2$$

$$n = \frac{n_i^2}{N_a}$$

Quiz: What happens to n and p in n-type Si as temperature increases

$$n \approx N_d$$

$$p \approx \frac{n_i^2}{N_d}$$



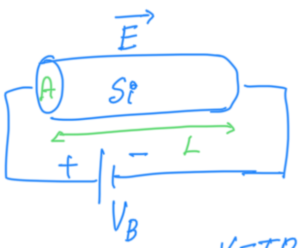
Summary:

	n-type N_d ($\sim 10^{15}-10^{17}$)	N_a p-type
majority	$n \approx N_d$	$p \approx N_a$
minority	$p \approx \dfrac{n_i^2}{N_d}$	$n \approx \dfrac{n_i^2}{N_a}$

★ Carrier Transport : Drif & Diffusion

Drift

Current conduction due to electric field.



$V = IR$

terminal velocity

$R = \rho \frac{L}{A}$

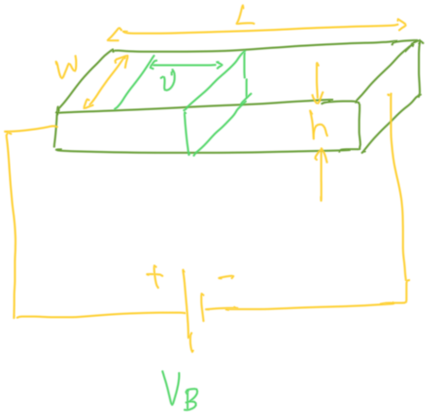
counterforce of e^- hitting atoms.
So terminal velocity

Velocity of e^- in Semi-cond^{r} $v \propto E$

$v = \mu_n E$

μ_n = electron mobility $= 1350\ cm^2/(V.s)$

Observation :



$E = \frac{V_B}{L}$ Voltage $= -\int \vec{E}\, dL$

current = charge passing through cross-section in 1 sec.

Total charge $= \underbrace{v.\,w.\,h}_{\text{total volume}}.\,\underbrace{n}_{\text{carrier density}}.\,\underbrace{q}_{\text{charge}} = |I|$

$= \mu_n \frac{V_B}{L} w.h.n.q$

So $R = \frac{L}{\mu_n . \underbrace{w.h}_{A}.n.q} = \frac{1}{\mu_n n q} \frac{L}{A}$

Current density $= I/cm^3$

$J_n = \mu_n E n q \quad A/cm^3$

Total current density (Drift) $= J = (\mu_n . n . q + \mu_p P . q) E$

$\mu_p \simeq 400\ cm^2/(V.s)$