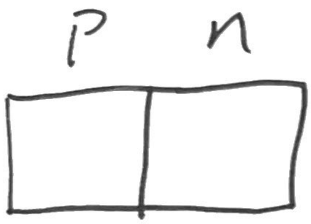
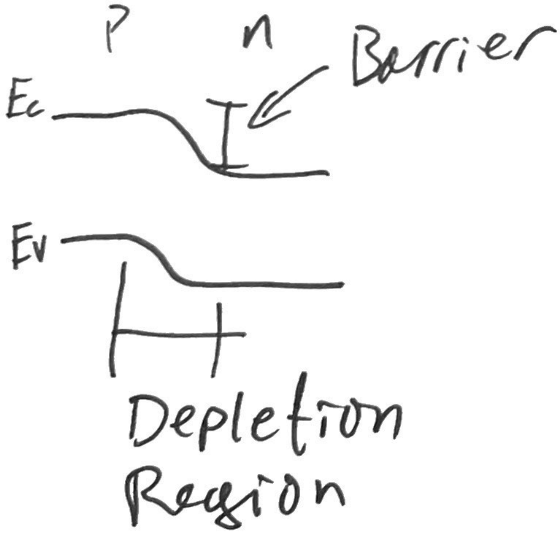
Semiconductors

- Bandgaps
- Bond Model
- Band model
- Doping
- Response to heat & light
- Diodes

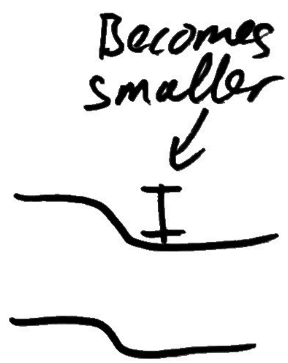


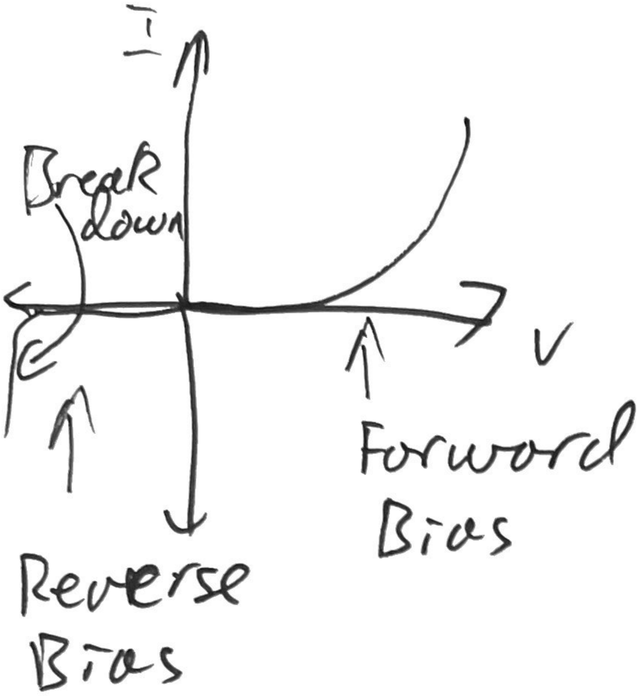
@ 0V



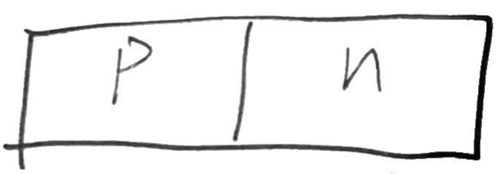
@ −2V

+0.7V





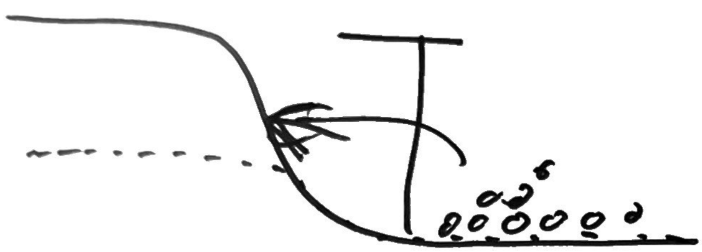
1. Define System

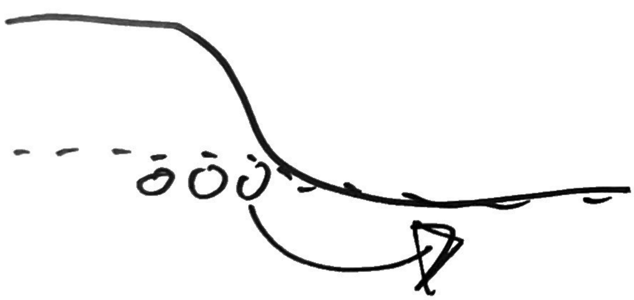


2. Write out governing equations
3. Solve equations
4. Simplify

Minority Carrier Diffusion Eqn.

$$\frac{d^2 \Delta p_n}{dx^2} = \frac{\Delta p_n}{D_p \tau_p} = \frac{\Delta p_n}{L_n}$$





$$\left.\begin{cases} \Delta p_n(x_n) = p_{n0}\left(e^{\frac{qV}{kT}} - 1\right) \\ \Delta p_n(\infty) = c \end{cases}\right\} \text{Boundary Conditions}$$

$$\Delta p_n(x) = A_1 e^{x/L_p} + A_2 e^{-x/L_p}$$

Le

$$\Delta P_n(x) = A_1 e^{x/L_P} + A_2 e^{-x/L_P}$$

$$\Delta P_n(\infty) = 0$$

$$\Delta P_n(\infty) = A_1 e^{\infty/L_P} + \cancel{A_2} e^{-\infty/L_P} = 0$$

$$A_1 = 0 \qquad A_2 = P_{n0}\left(e^{\frac{qV}{kT}} - 1\right)$$

$$\rightarrow \Delta P_n(x) = P_{n0}\left(e^{\frac{qV_A}{kT}} - 1\right) e^{-x/L_P} \quad x > 0$$

$$-\Delta n_p(x) = n_{p0}\left(e^{\frac{qV}{kT}} - 1\right) e^{-x/L_n}$$

$\downarrow$

Do more physics + math

$$J = q n_i^2 \left[\frac{D_n}{L_n N_A} + \frac{D_p}{L_p N_D}\right]\left(e^{\frac{qV_A}{kT}} - 1\right)$$

$$J = J_0\left(e^{\frac{qV_A}{kT}} - 1\right)$$

$$I = (J_0 \cdot A)\left(e^{\frac{qV_A}{kT}} - 1\right) = \boxed{I_0\left(e^{\frac{qV_A}{kT}} - 1\right)}$$

$$I = I_0\left(e^{\frac{qV}{\eta KT}} - 1\right)$$

q = charge of an e^-

V = applied bias ($+V \rightarrow$ forward
$-V \rightarrow$ reverse)

η = idealoty factor $1 < \eta < 2$

K = Boltzmann constant

T = temp. in Kelvin

Doping

Density of Si $\sim 5 \times 10^{22} \frac{\text{atoms}}{\text{cm}^3}$

Doping $\rightarrow$ $\sim 10^{15} \frac{\text{Dopants}}{\text{cm}^3}$

$\downarrow$

$10^{18} \frac{\text{Dopants}}{\text{cm}^3}$

Si $10^{23} \frac{\text{atoms}}{\text{cm}^3}$

Impurities $\sim 10^{21} \frac{\text{atom}}{\text{cm}^3}$

Boron $10^{15} \frac{\text{atoms}}{\text{cm}^3}$

$\uparrow$

$\frac{10^{21}}{10^{23}} = 0.01$

$\times 100$

1% imp.

99% pure

I need to purify Si down to what level so that my doping of $10^{15} \frac{\text{B atoms}}{\text{cm}^3}$ represents 99% + of all impurities

$10^{15} \frac{\text{B atoms}}{\text{cm}^3}$

$10^{13} \frac{\text{impurities}}{\text{cm}^3}$

$100\left(\frac{X}{10^{15}}\right) = 1\%$

$100 \times \frac{10^{13}}{10^{15}} = 1\%$

Si $10^{23} \frac{\text{Si atoms}}{\text{cm}^3}$

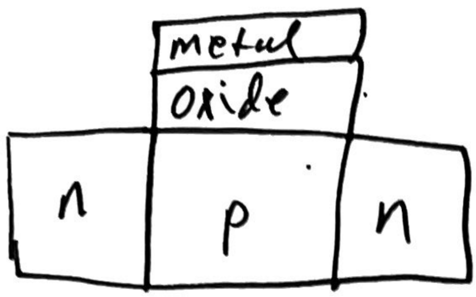
Imp $10^{13} \frac{\text{atoms}}{\text{cm}^3}$

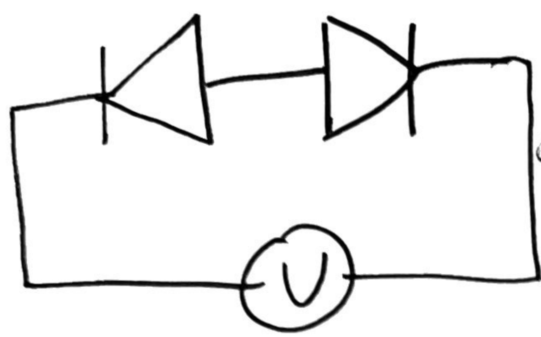
$100\left(\frac{10^{13}}{10^{23}} = 10^{-10}\right)$

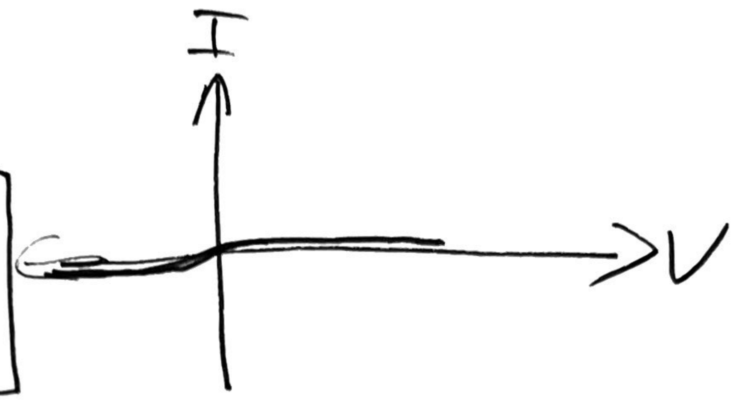
$= 10^{-8}\%$

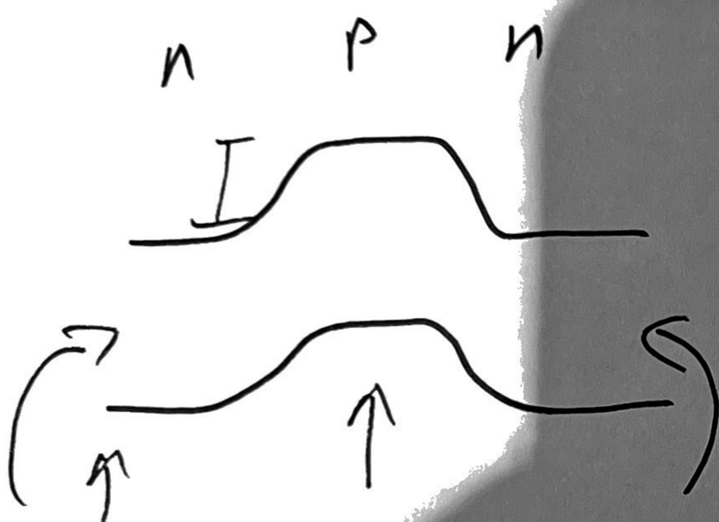
$100 - 10^{-8} =$

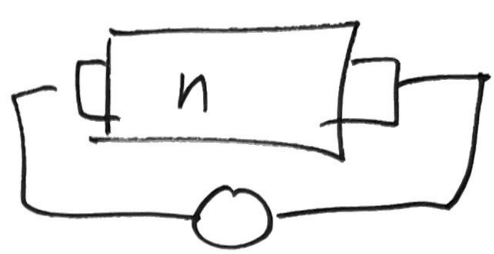
99.99999999% pure

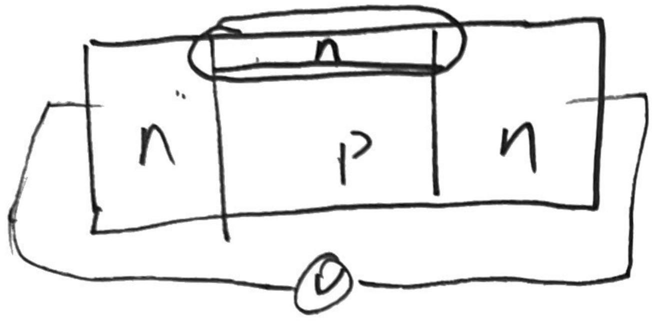

metal
oxide
n
p
n

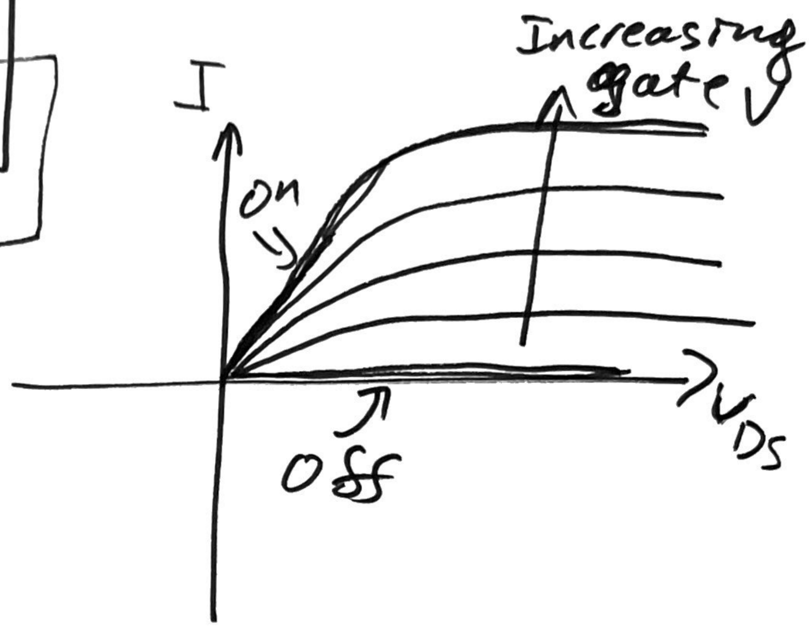

V


I
V

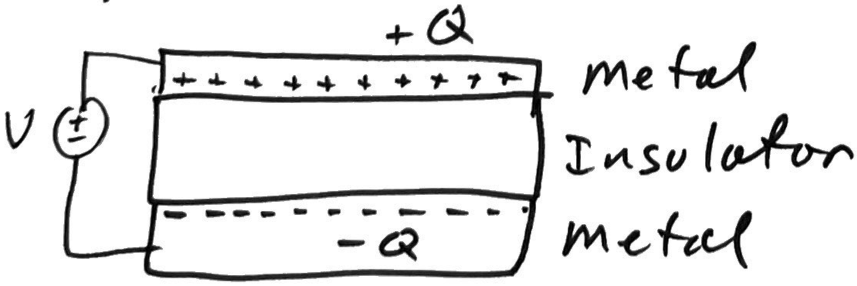

n
p
n
I







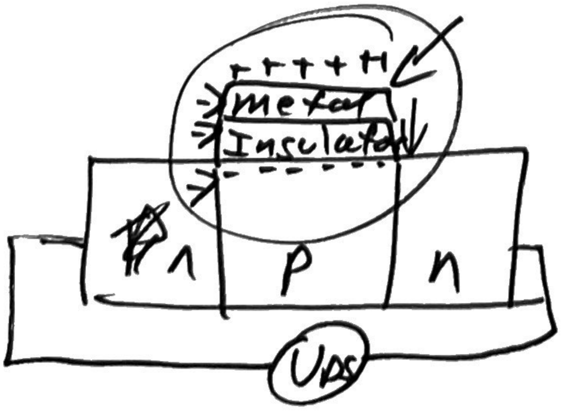
Capacitor



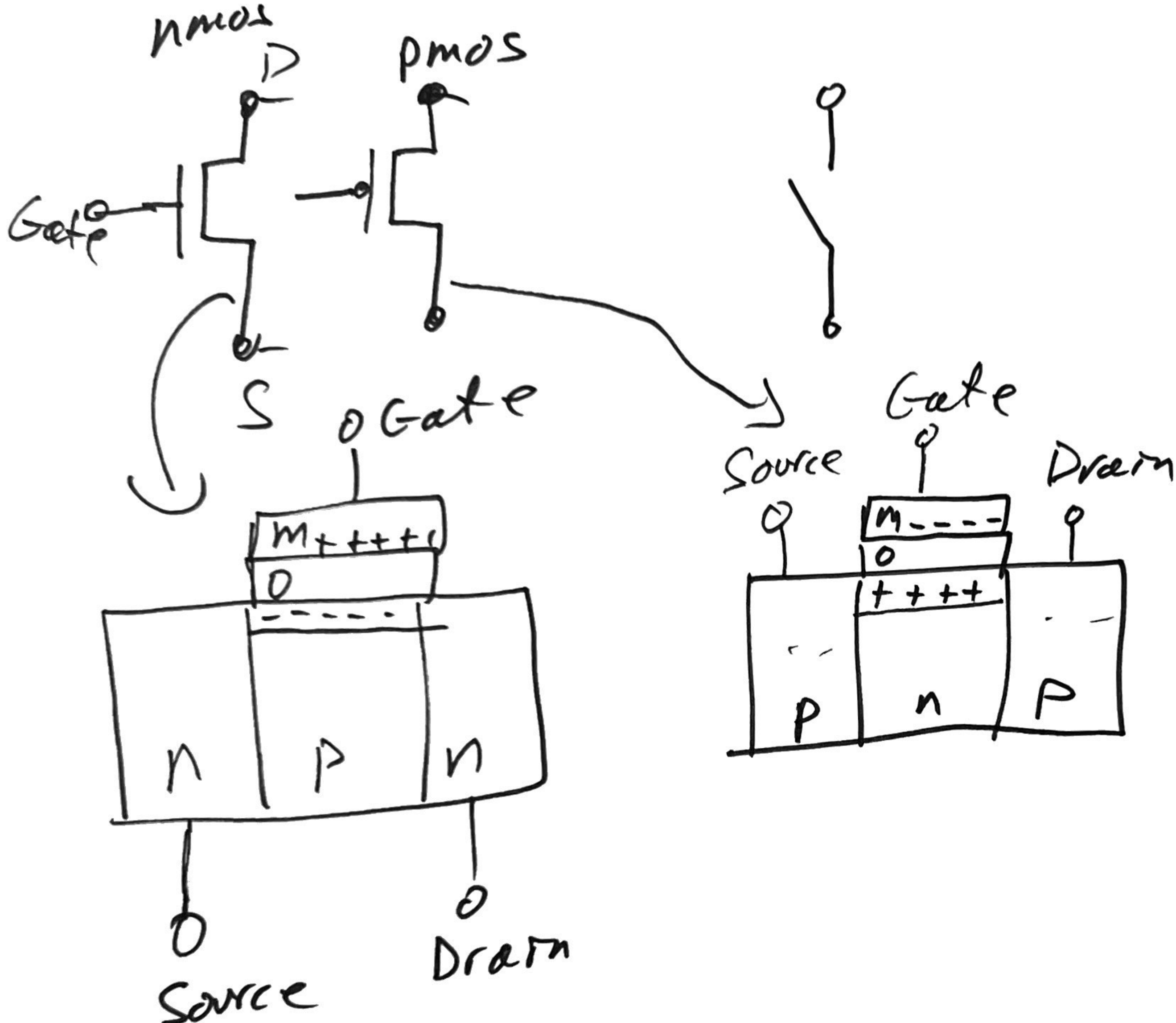
$$Q = CV$$

$$\frac{dQ}{dt} = C\frac{dv}{dt}$$

$$i = C\frac{dv}{dt}$$



→ MOSFET

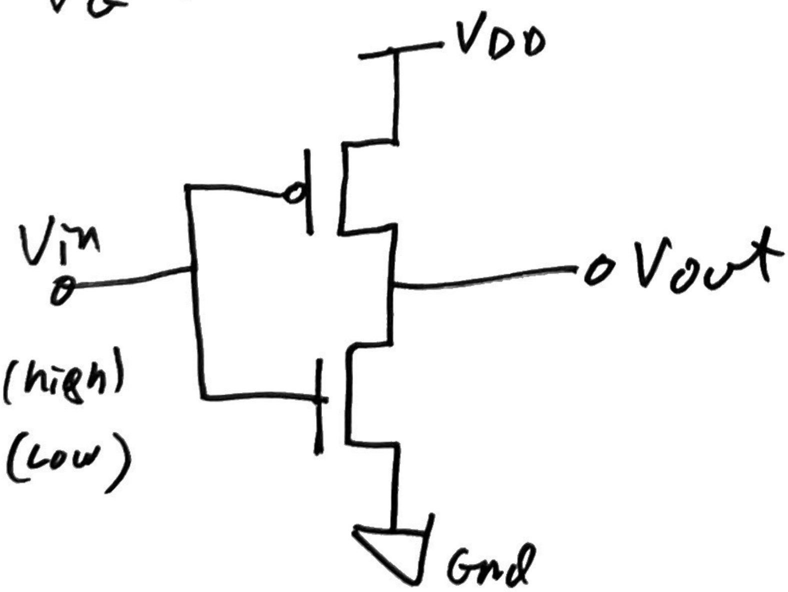


nmos

V_G positive

pmos

V_G negative



VDD (high)

Gnd (Low)