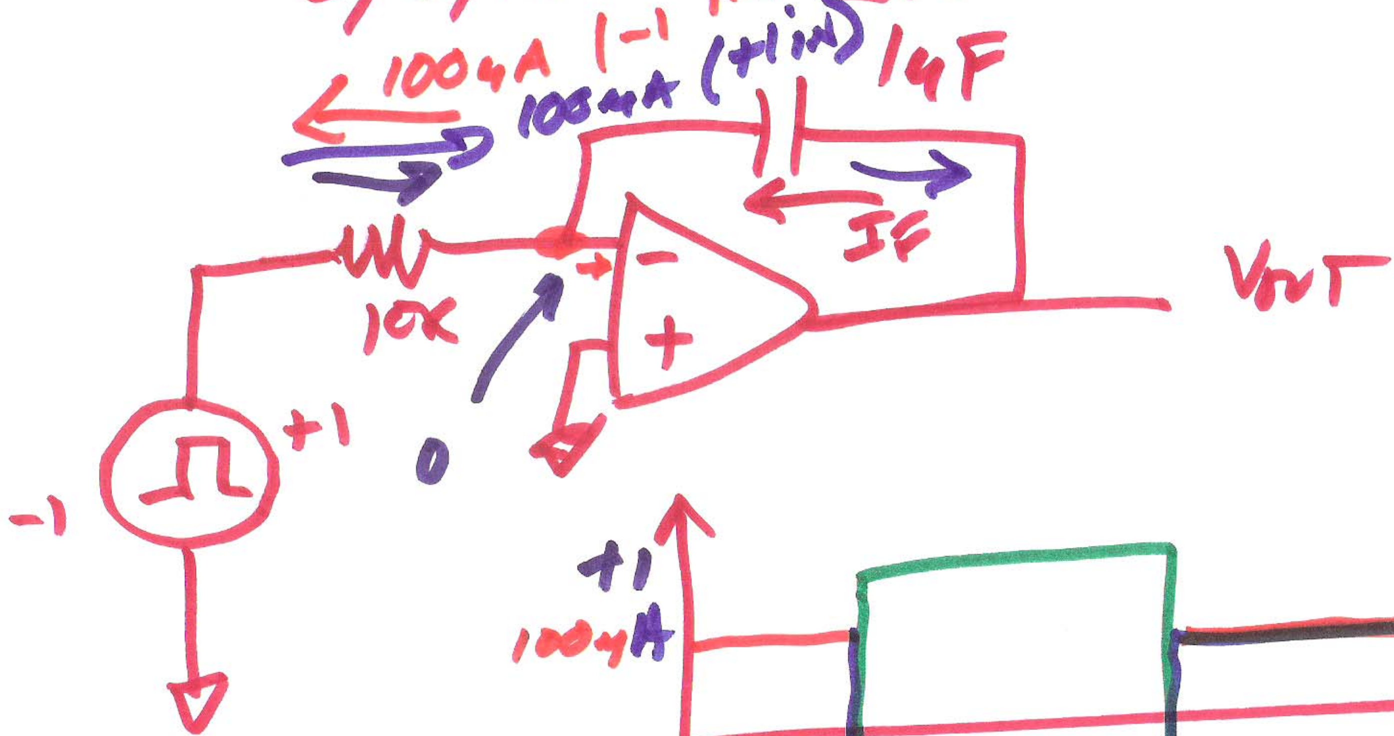
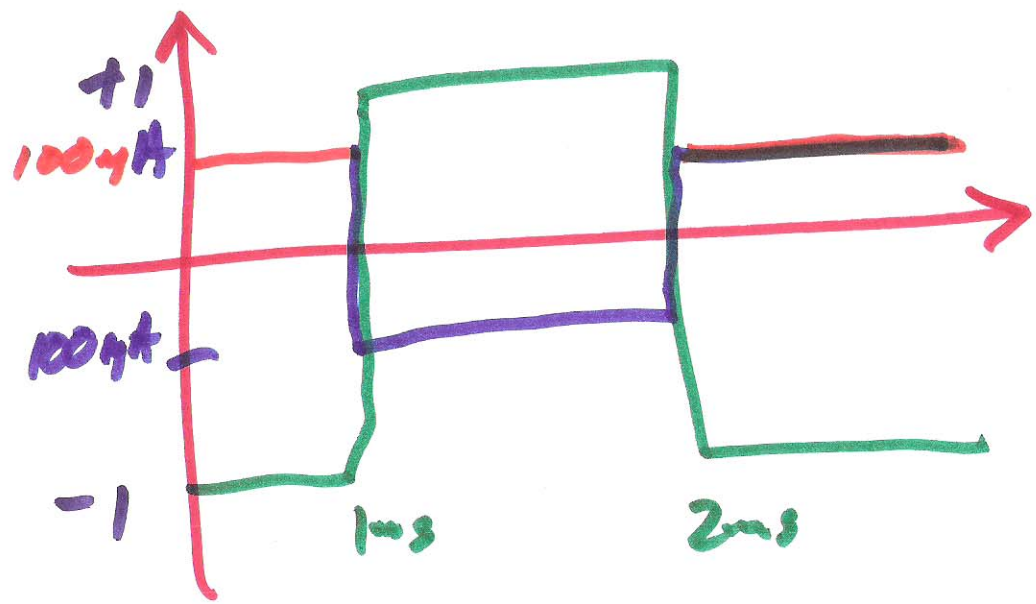
EE 320 Electronics

2/6/13 Lecture 5





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intrinsic Si

$N = P = N_i$

Valence e 4

N_i = intrinsic carrier concentration

$\frac{\text{Atoms}}{\text{cm}^3} \leftarrow N_D$ – Donor Atoms, e.g. P (valence e 5)

$N_A = 0$

N

$N \simeq N_D$

$$P = \frac{N_i^2}{N} = \frac{N_i^2}{N_D}$$

$N \rightarrow$ Carriers/$\text{cm}^3 \leftarrow P$

N_A – Acceptor atoms, B (valence of 4)

P

$P \simeq N_A$ (complete ionization)

$$N = \frac{N_i^2}{P} = \frac{N_i^2}{N_A}$$

Dope with N_A & N_D

$$N_D \gg N_A$$

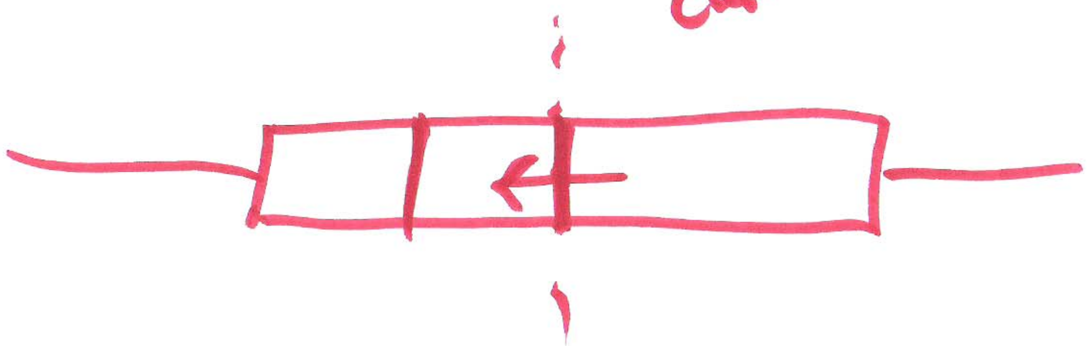
N-type semiconductor

$$n \approx N_D - N_A$$

$$p = \frac{n_i^2}{N_D - N_A}$$

$\rightarrow J = Q \cdot v =$ current density,

$$\frac{C}{cm^3} \cdot \frac{cm}{s} \qquad A/cm^2$$



$- \xleftarrow{\mathcal{E}} +$ Mobility

$$\mu_{N,P} = \frac{\text{velocity, cm/s}}{\mathcal{E},\ \text{V/cm}}, \quad \frac{\text{cm}^2}{\text{V}\cdot\text{s}}$$

$$J_N^{drift} = Q_N \cdot v_N = (-qN)(-\mu_N E)$$

$$J_P^{drift} = Q_P \cdot v_P = (+qP)(+\mu_P E)$$

$$J_{total}^{drift} = J_N^{drift} + J_P^{drift}$$

$$J_{total}^{drift} = \underbrace{q(N\mu_N + P\mu_P)}_{\sigma = \frac{1}{\rho}}\,\mathcal{E}, \quad \text{Ohm's law}$$

$$\rho = \frac{1}{q\cdot(n\cdot\mu_n + p\cdot\mu_p)} = \text{resistivity}$$

$$= \frac{1}{\cancel{C}\cdot\left(\frac{\text{carriers}}{cm^{\cancel{3}}}\cdot\frac{\cancel{cm^2}}{V\cdot S}\right)}$$

$1.6\times10^{-19}\,C$

$$= \frac{1}{\frac{A}{V}}\cdot cm$$

$$= \Omega\cdot cm$$

5)

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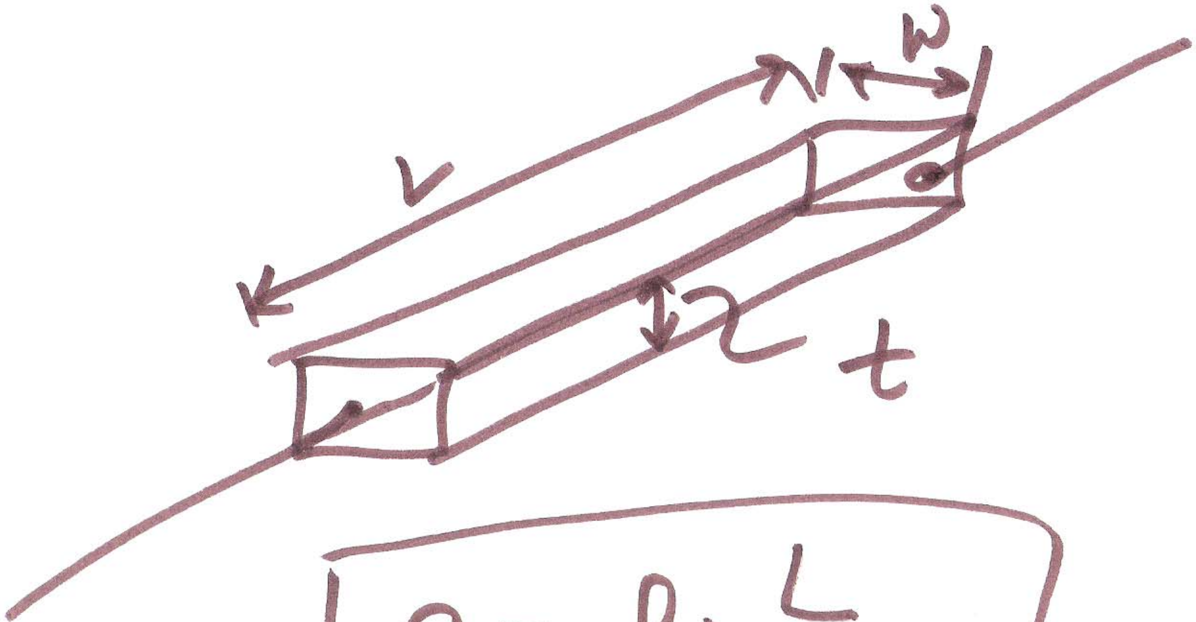

$$\boxed{R = \rho \cdot \frac{L}{t \cdot W}}$$

2.28 $\quad N_A = 2 \times 10^{18}$ atoms/cm3

$N_A = 8 \times 10^{18}$ atoms/cm3

a) $N_A > N_D \rightarrow$ p-type

b) $p = ?$ $\quad N = ?$

$$p = N_A - N_D$$

$$N = \frac{N_i^2}{p} = \frac{N_i^2}{N_A - N_D}$$

2.30) $N_D = 10^{16}$ Atoms/cm^3

$N_A = 5 \times 10^{16}$ Atoms/cm^3

$N_i = 10^{11}$ CARRIERS/cm^3

$N = ?$ $\quad$ $p = ?$

p-type

$p = N_A - N_D = 4 \times 10^{16}$

$$N = \frac{N_i^2}{p} = \frac{10^{22}}{4 \times 10^{16}} = \frac{1}{4} \times 10^6$$

$$= \underline{\underline{250{,}000}}$$

2.34) p-type , $N_A = 2.5 \times 10^{18} \frac{\text{Atoms}}{cm^3}$

$$n_i^2 \Big|_{@300K} = 4.52 \times 10^{19} \text{ carriers}^2/cm^6$$

$$n = \frac{n_i^2}{N_A} = \frac{4.52 \times 10^{19}}{2.5 \times 10^{18}}, \frac{\text{carriers}}{cm^3}$$

$$\mu_n = 1350 \; cm^2/V \cdot s$$

$$\mu_p = 80 \; cm^2/V \cdot s$$

$$\rho = \frac{1}{q(n \cdot \mu_n + p \cdot \mu_p)}$$

$$\approx \frac{1}{q \cdot \underbrace{\cancel{p}}_{2.5\times10^{18}} \cdot \underbrace{\cancel{\mu_p}}_{80}}, \; \Omega \cdot cm$$

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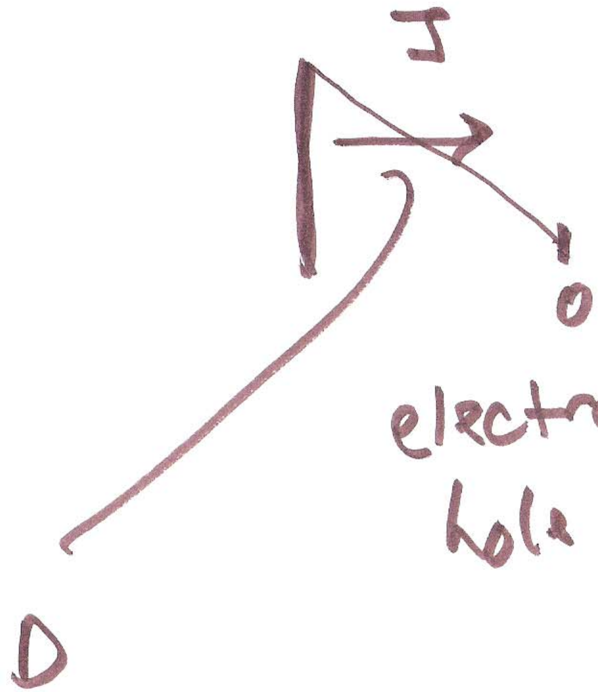

electron diffusion
hole diffusion

$$J_p = q D_p \left(\frac{-\delta p}{\delta x} \right)$$

$$J_N = -q D_N \cdot \frac{\delta N}{\delta x}$$

Read sec. 2.8 & 2.9