Your Name:__________________

3.225 Quiz 2007

$e=1.602\text{x}10^{-19}$ C
$m_o=9.11\text{x}10^{-31}$ kg
$c=2.998\text{x}10^{8}$ m/sec
$\varepsilon_o=8.854\text{x}10^{-12}$ F/m
$k_b=1.38\text{x}10^{-23}$ J/K
$h=6.626\text{x}10^{-34}$ J-sec
$\hbar=1.054\text{x}10^{-34}$ J-sec
$A=6.022\text{x}10^{23}$ mole^{-1}

1. 1-D Silicon

Silicon has a valence 4, a=0.5428nm

(a) Using the Drude model, calculate the estimated conductivity along the 1-D wire

$$n=\frac{Z}{a}=\frac{4}{a},\sigma=\frac{ne^2\tau}{m_0}\rightarrow \text{calculate using } \tau = 10^{-14}s$$

(b) What is the plasma frequency?

$$\omega_p=\sqrt{\frac{ne^2}{m_0\varepsilon_0}}$$

c) Now let us have electron waves instead of electron particles in our 1-D Si; determine k_F and E_F

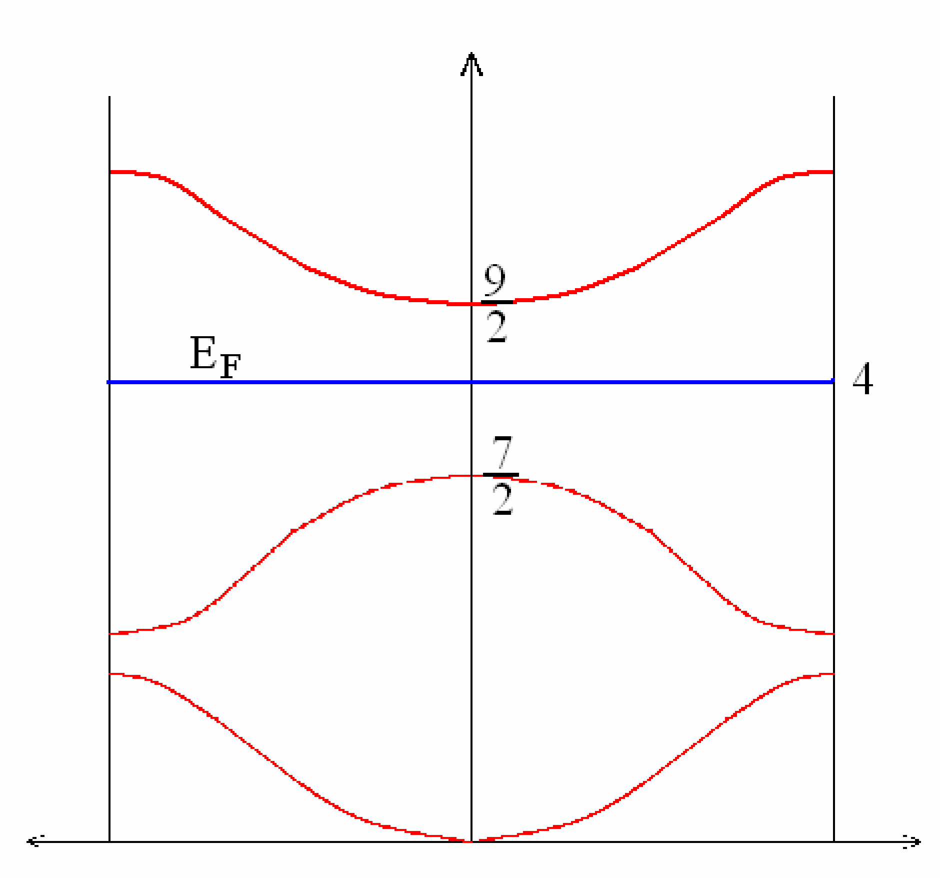
$$k_F{}^{1-d}=\frac{n\pi}{2},n=\frac{4}{a}\Rightarrow k_F{}^{1-d}=\frac{2\pi}{a}$$
$$E_F{}^{1-d}=\frac{\hbar^2 k_F{}^2}{2m}=\frac{2\pi^2\hbar^2}{m^* a^2}$$

(d) Derive the density of states for the 1-D Si for free electron waves

$$g(E)^{1\text{-d}} = \frac{dN}{dk}\frac{dk}{dE}\frac{1}{L}, \; N = \frac{2kL}{\pi}, \; k = \frac{\sqrt{2mE}}{\hbar}$$

$$\Rightarrow g(E)^{1\text{-d}} = \frac{\sqrt{2m}}{\pi\hbar}\frac{1}{\sqrt{E}}$$

(e) If the band gap of interest is ($\hbar^2\pi^2/(2m_0a^2)$), draw the E vs. band structure for nearly free electron silicon



2. 2-D Semiconductor

(a) Derive the density of states for a 2-D semiconductor, $g(E)=m^*/(\pi\hbar^2)$

$$g(E)^{2\text{-d}}=\frac{dN}{dk}\frac{dk}{dE}\frac{1}{L},\ N=\frac{k^2L^2}{2\pi},\ k=\frac{\sqrt{2m^*E}}{\hbar}$$

$$\Rightarrow g(E)^{2\text{-d}}=\frac{m^*}{\pi\hbar^2}$$

(b) Assume that $E_g = 1.1\text{eV}$ for this intrinsic 2-D semiconductor (i.e. same as for 3-D Si). Calculate n at room temperature and compare to 3-D Si, where $n = 10^{10}\ \text{cm}^{-3}$ for intrinsic material. Assume $m^*=m_0$.

Number of e^- per area in conduction band = n (as 2-d semi conductor)

$$n = \int_{E_C}^{\infty} f(E)g^{2\text{-d}}(E)dE,\ f(E)\sim\ \exp\left(-\frac{E-E_F}{k_bT}\right),\ E_F = \frac{E_g}{2}\ \text{and}\ E_C = E_g\ \text{(as intrinsic)}$$

$$g^{2\text{-d}}(E)= \frac{m^*}{\pi\hbar},\ \Rightarrow\ n = \int_{E_C}^{\infty} f(E)g^{2\text{-d}}(E)dE = \frac{m^*}{\pi\hbar}\int_{E_g}^{\infty}\exp\left(-\frac{E}{k_bT}+\frac{E_g}{2k_bT}\right)dE$$

$$\Rightarrow\ n = \frac{m^*k_bT}{\pi\hbar}\ \exp\left(-\frac{E_g}{2k_bT}\right)$$

$n^{2\text{-d}} < n^{3\text{-d}}$ as unlike $g^{3\text{-d}}(E)$, $g^{2\text{-d}}(E)$ is not an increasing function of E (in fact it is a constant).

3. Dielectric Properties

Describe $\varepsilon(\omega)$ for 1-D Si in the context of the sources of polarization.

Just electronic polarization…draw $\varepsilon(\omega)$ vs ω. Show ω_{oe} etc.