# ECE 656: Fall 2009
# Lecture 10 Homework SOLUTION

1) In Lecture 8, we developed a current equation for electrons in the presence of a gradient in the electrochemical potential and temperature as

$$J_{nx} = \sigma_n \frac{d(F_n/q)}{dx} + [SG]\frac{dT}{dx}$$

where

$$\sigma_n(E) = \frac{2q^2}{h}\lambda(E)\frac{M(E)}{A}\left(-\frac{\partial f_0}{\partial E}\right)$$

and

$$[SG] = +\left(\frac{k_B}{q}\right)\int \sigma_n(E)\left(\frac{E-E_F}{k_BT}\right)dE$$

1a) Assume a 3D non-degenerate n-type semiconductor with a constant mfp and evaluate the two parameters, $\sigma_n$ and [SG].

1b) Give a physical explanation for the sign of [SG].

HW10 Solution

1a) $G = \frac{2q^2}{h} I_0$ $\qquad I_0 = \int T(E) M(E) \left(-\partial f_0 / \partial E\right) dE$

$T(E) = \lambda_0 / L$

$M(E) = A \cdot m^* E / 2\pi\hbar^2$

$$G = \sigma \frac{A}{L} = \frac{2q^2}{h} I_0$$

$$\sigma = \frac{L}{A} \cdot \frac{2q^2}{h} I_0$$

$$I_0 = \frac{\lambda_0 m^*}{2\pi\hbar^2} \int (E - E_C) \left(-\frac{\partial f_0}{\partial E}\right) dE$$

$$= \frac{\lambda_0 m^*}{2\pi\hbar^2} \left(+\frac{\partial}{\partial E_F}\right) \int \frac{E - E_C}{1 + e^{(E-E_F)/k_BT}} dE$$

$$= \frac{\lambda_0 m^*}{2\pi\hbar^2} \left(\frac{\partial}{\partial E_F}\right) \int \frac{\eta \, d\eta}{1 + e^{\eta - \eta_F}} \times (k_BT)^2$$

$$= \frac{\lambda_0 m^* k_BT}{2\pi\hbar^2} \cdot \frac{\partial}{\partial \eta} \mathcal{F}_1(\eta)$$

$$\sigma = \frac{2q^2}{h} \cdot \frac{\lambda_0 m^*}{2\pi\hbar^2} \mathcal{F}_0(\eta_F)$$

1a) cont

non-degenerate conditions

$$\sigma = \frac{2q^2}{h} \frac{\lambda_0 m^*}{2\pi\hbar^2} e^{\eta_F} \qquad n_0 = N_C e^{\eta_F}$$

$$N_C = \frac{1}{4}\left(\frac{2m^* k_B T}{\pi\hbar^2}\right)^{3/2}$$

the final result is

$$\sigma = n_0 q \mu_n \qquad \mu_n = \frac{v_T \lambda_0}{2} \times \frac{1}{(k_B T/q)}$$

For a non-degenerate semic.

$$S = -\left(\frac{k_B}{q}\right)(2-\eta_F) = -\frac{SG}{G}$$

$$[SG] = \sigma \times \left(\frac{k_B}{q}\right)(2-\eta_F) \qquad \eta_F = \ln(n_0/N_C)$$

$$= n_0 q \mu_n \frac{k_B}{q}\left(2 + \ln(N_C/n_0)\right)$$

$$[SG] = n_0 \mu_n k_B \ln(N_C/n_0)$$