SOLUTION

ECE 656: Fall 2009

Lecture 15 Homework SOLUTION

(Revised 9/27/09)

In Lecture 15, we showed that the Seebeck coefficient for a 3D, non-degenerate semiconductor with parabolic energy bands is:

$$S_0 = \frac{k_B}{(-q)}\left\{\left(\frac{E_C - F_n}{k_B T}\right) + \frac{3\langle E^2\tau\rangle}{2\langle E\rangle\langle E\tau\rangle}\right\}$$

1) Work out the result assuming a constant scattering time.

2) Work out the result assuming a constant mean-free-path.

HW 15

let's see if we can make use of prior results.

$$\frac{3}{2}\frac{\langle E^2\tau\rangle}{\langle E\rangle\langle E\tau\rangle} = ?$$

$$= \frac{3}{2}\frac{\langle E^2\tau\rangle}{\langle E\rangle^2}\frac{\langle E\rangle}{\langle E\tau\rangle} \longrightarrow = \frac{\Gamma(5/2)}{\Gamma(s+5/2)}$$

$$? = \frac{\langle E\cdot(E/k_BT)\,\tau_0(E/k_BT)^s\rangle}{\langle E\rangle}\cdot\frac{k_BT}{\langle E\rangle}$$

$$= \frac{\langle E\tau'\rangle}{\langle E\rangle}\cdot\frac{k_BT}{\langle E\rangle} \qquad \tau' = \tau_0(E/k_BT)^{s+1}$$

$$= \frac{\Gamma(s+7/2)}{\Gamma(5/2)}\cdot\frac{k_BT}{3/2\,k_BT}$$

so

$$\frac{3}{2}\frac{\langle E^2\tau\rangle}{\langle E\rangle\langle E\tau\rangle} = \cancel{\frac{3}{2}}\,\frac{\Gamma(s+7/2)}{\cancel{\Gamma(5/2)}}\cdot\frac{1}{\cancel{3/2}}\cdot\frac{\cancel{\Gamma(5/2)}}{\Gamma(s+5/2)}$$

$$= \frac{\Gamma(s+7/2)}{\Gamma(s+5/2)}$$

HW15

1) constant scattering time $s=0$

$$\frac{3}{2}\frac{\langle E^2\tau\rangle}{\langle E\rangle\langle E\tau\rangle} = \frac{\Gamma(7/2)}{\Gamma(5/2)} \qquad \Gamma(p+1)=p\Gamma(p)$$

$$\Gamma(7/2) = \frac{5}{2}\Gamma(5/2)$$

$$= 5/2$$

$$S = \frac{k_B}{(-q)}\left\{\frac{E_c - F_n}{k_B T} + 5/2\right\} \checkmark$$

2) constant mfp $\quad mfp \sim v\tau$
$\sim E^{1/2}(E)^s$

$$\Rightarrow s = -1/2$$

$$\frac{3}{2}\frac{\langle E^2\tau\rangle}{\langle E\rangle\langle E\tau\rangle} = \frac{\Gamma(3)}{\Gamma(2)} \qquad \Gamma(n) = (n-1)!$$

$$= 2$$

$$S = \frac{k_B}{(-q)}\left\{\frac{(E_c - F_n)}{k_B T} + 2\right\} \checkmark$$

2)