<u>ECE 543</u>

FINAL EXAM

Tuesday/Wednesday 4/5 May 2004

Note 1: This exam is 'open book,' 'open notes,' 'open homework' and you may consult the palm and Tarot card readers in the Union. There is no smoking during the exam.

Note 2: The exam is due: 5 May at 1200.

Note 4: I have worked very hard to maximize your entertainment pleasure. Please Have FUN!!!

Question 1 Consider the homogeneous, non-equilibrium, 1-dimension distribution function given by:

$$f(p_x) = a_1\,\delta(p_x + p_1) \; + \; a_2\,\delta(p_x) \; + \; a_3\,\delta(p_x - p_2) \tag{1}$$

where a_1, a_2, a_3, p_1, and p_2 are all positive constants. Assume parabolic bands such that

$$E(p_x) = \frac{p_x^2}{2m^*} \tag{2}$$

and power-law scattering so that

$$\tau_m(p) = \tau_0 \left(\frac{E}{kT}\right)^s$$

where τ_0 is a constant and the characteristic exponent $s = -\frac{1}{2}$.

Calculate

1. the electron density n
2. the total current J_x
3. the average momentum relaxation rate $\left\langle \frac{1}{\tau_m} \right\rangle$
4. the average ensemble momentum relaxation rate $\left\langle \left\langle \frac{1}{\tau_m} \right\rangle \right\rangle$

Question 2 Consider a n–type, non-degenerate, silicon wafer, subjected to a uniform electric field $\mathcal{E}(\mathbf{r})$. Assume the 3-dimension electron distribution function $f(\mathbf{p})$ is described by:

$$f(\mathbf{p}) = f_0(\mathbf{p}) + f_A(\mathbf{p}) \tag{3}$$

where $f_0(\mathbf{p})$ is the equilibrium distribution function and $f_A(\mathbf{p}) << f_0(\mathbf{p})$ is an anti–symmetric (odd) function in $\mathbf{p}$ which can be determined using the relaxation time approximation. Assume parabolic bands such that

$$E(\mathbf{p}) = \frac{p^2}{2m^*} \tag{4}$$

and power-law scattering so that

$$\tau_f(\mathbf{p}) = \tau_0 \left(\frac{E}{kT}\right)^s$$

where τ_0 is a constant and the characteristic exponent $s = -\frac{1}{2}$. Calculate

1. electron density $\mathbf{n}$
2. total current J_x (along one axis)
3. relaxation time give by: $\langle\langle \tau_f \rangle\rangle = \frac{\langle E\tau_f(E)\rangle}{\langle E\rangle}$
4. the quantity: $\left\langle\left\langle \tau_f^3 \right\rangle\right\rangle$

Express your answers in terms of Gamma Functions.

Question 3 Acoustic deformation potential (ADP) scattering

The general momentum relaxation rate for phonon scattering is given by:

$$\frac{1}{\tau_m} = \frac{\Omega}{4\pi^2} \int_{\beta_{min}}^{\beta_{max}} \left(N_\beta + \frac{1}{2} \mp \frac{1}{2}\right) C_\beta \left(\frac{\hbar\beta}{2p} \mp \frac{\omega}{\nu\beta}\right) \frac{\hbar\beta^3}{p}\, d\beta \tag{5}$$

(see equation 2.80)

Part a) Consider the case of acoustic deformation potential (ADP) scattering. Assume that the scattering is elastic and near room temperature. Under these conditions, derive an expression for the momentum relaxation rate. (Note, do not express your answer in terms of the density of states.)

Part b) Without assuming that the scattering is elastic, derive an expression for the momentum relaxation rate near room temperature and show that this result is the same as the result in Part a) multiplied by a real number. What is this number?

Note: show all work.