PHYSICS 210B : NONEQUILIBRIUM STATISTICAL PHYSICS
HW ASSIGNMENT #5 : BOLTZMANN EQUATION

(1) Consider a monatomic ideal gas in the presence of a temperature gradient $\boldsymbol{\nabla} T$. Answer the following questions within the framework of the relaxation time approximation to the Boltzmann equation.

(a) Compute the particle current $\boldsymbol{j}$ and show that it vanishes.

(b) Compute the 'energy squared' current,

$$\boldsymbol{j}_{\varepsilon^2} = \int d^3\!p \, \varepsilon^2 \boldsymbol{v} \, f(\boldsymbol{r}, \boldsymbol{p}, t) \ .$$

(c) Suppose the gas is diatomic, so $c_p = \frac{7}{2} k_{\rm B}$. Show explicitly that the particle current $\boldsymbol{j}$ is zero. *Hint: Note that the gas is diatomic. You may assume* $\boldsymbol{V} = \boldsymbol{F} = 0$.

(2) Suppose the relaxation time is energy-dependent, with $\tau(\varepsilon) = \tau_0 \, e^{-\varepsilon/\varepsilon_0}$. Compute the particle current $\boldsymbol{j}$ and energy current $\boldsymbol{j}_\varepsilon$ flowing in response to a temperature gradient $\boldsymbol{\nabla} T$.

(3) Use the linearized Boltzmann equation to compute the bulk viscosity ζ of an ideal gas.

(a) Consider first the case of a monatomic ideal gas. Show that $\zeta = 0$ within this approximation. Will your result change if the scattering time is energy-dependent?

(b) Compute ζ for a diatomic ideal gas.