

## 22.103 Microscopic Theory of Transport

(Fall 2003)

### Problem Set No. 1

Due: September 19, 2003

#### Problem 1

(a) Discuss the physical meaning of the diffusion coefficient  $D$  through the phenomenological expression, Fick's law, where you carefully define the quantities that appear in this expression. Extend your discussion to the other two transport coefficients, the shear viscosity  $\eta$  and thermal conductivity  $\kappa$ , using expressions analogous to the Fick's law.

(b) For a simple fluid, discuss briefly whether you expect the three transport coefficients to show the same dependence on density (pressure) and temperature. What physical processes are responsible for the variation of these transport coefficients with density and temperature? How would one go about calculating (predicting) these variations, in other words, what theoretical approach is available?

#### Problem 2

Derive the mean squared displacement function  $\langle \Delta^2 r(t) \rangle$  for an ideal gas of particles with mass  $M$  at temperature  $T$ .

#### Problem 3

Sketch the behavior of  $\langle \Delta^2 r(t) \rangle$  for an ideal gas, a liquid, and a solid, and discuss the qualitative features of this function for the three states of matter (differences and similarities). Based on these features, what can you infer about the atomic motions in these three idealized models of physical systems?

#### Problem 4

Derive the Green-Kubo expression for the diffusion coefficient  $D$  in terms of the normalized velocity autocorrelation function  $\psi(t)$ . Repeat Problem 3 for  $\psi(t)$  instead of  $\langle \Delta^2 r(t) \rangle$ .