Problem Set I: Due Wednesday, January 21, 2015

1.) Derive by heuristic methods the thermal diffusivity and shear viscosity for a dilute gas of particles undergoing hard sphere interactions.

2.) Consider a heavy particle of mass M, radius d_2 in a gas of light particles of mass m, radius d_1 $(m << M, d_2 > d_1)$ at temperature T.

a.) Estimate the mobility of the heavy particle.

b.) When will the heavy particle be fully deflected from its trajectory? What is the deflection length?

c.) When will the energy of the heavy particle equal that of the light background particle?

3.) Use the result from Problem 2 to estimate the time scale for thermal equilibration of ions of mass M_i and temperature T_i with electrons of mass m_e and T_e. Take $T_e > T_i$. Compare this time scale with the electron-electron and ion-ion collision times.

4.) Derive the dielectric function $\in(k,\omega)$ for Langmuir waves, incorporating electron pressure effects. Hint: Work with displacement to calculate polarization. What is the dispersion relation?

5.) a.) Calculate the dispersion relation for a surface wave on a fluid of finite depth d. Discuss the limits $kd << 1$, $kd >> 1$.

b.) Based on your answer for $kd << 1$, guess the shallow water equations, for fluid motion in a thin layer? Then read the discussion of shallow water waves in Landau and Lifshitz "Fluid Mechanics" and explain the applicability, structure, limitations, etc. of these equations.

c.) What is the analogue of a shock front in the shallow water system?