PY 542: Non-Equilibrium Statistical Physics   Problem Set 5, Fall 2011

Reading: This week I will give a brief overview of kinetic theory, linear transport theory, and some basic consequences of hydrodynamics. These topics are not covered in the text, but there are many information sources. For kinetic theory, I recommend chapter 12 of Reif's text on statistical physics, but other advanced undergraduate statistical physics texts can be consulted. I also highly recommend the Feynman Lectures on Physics, volume II, chapters 40 & 41 for masterful treatments of non-viscous and viscous hydrodynamics.

Problems: Due Monday, October 10 by 5:00pm

1. *Reif 12.12* A long cylindrical wire of radius a and electrical resistance R per unit length is stretched along the axis of a long cylindrical container of radius b. The outer walls of this container are maintained at a fixed temperature T_0 and the container is filled with a gas of thermal conductivity κ. Compute the temperature difference ΔT between the wire and the container walls when a small electrical current I passes through the wire. Determine the thermal conductivity κ in terms of ΔT.

2. Consider the formation of a layer of ice on the top of pond in the winter. Assume that the water in the pond is always at temperature 0°C, while the air above the pond is fixed at a temperature $T_0 < 0$. (a) How does the thickness of the ice grow with time? (b) Using reasonable numerical values for physical parameters (such as the latent heat of melting) and $T_0 = -10$°C, estimate numerically how the ice thickness grows with time. Make simplifying assumptions wherever needed.

3. Estimate the shear viscosity of a typical molecular liquid, e.g., water. Under the assumption of slow flow, numerically estimate the terminal velocity for a steel sphere with radius $a = 1$cm that is falling in water under the action of gravity. How fast should the sphere fall for the "slow" approximation to fail?

4. A solid cylinder of length L, radius a, and mass m initially spins about its axis with angular frequency ω_0. The cylinder is supported by a central shaft with no frictional loss at the support points. The cylinder is enclosed by a cylindrical shell of radius b that is slightly larger than a. The region between the cylinders is filled with air at room temperature and atmospheric pressure. Under the assumption that the gas is in a state of linear shear between the cylinder and its enclosure, find the drag force exerted on the solid cylinder. Determine the equation of motion of the cylinder and solve for $\omega(t)$. Find the analytical expression for the time needed until $\omega(t) = 0.01 \times \omega_0$ and estimate this decay time numerically for $m = 1$ kg, $L = 10$ cm, $a = 5$ cm, $b = 5.1$ cm.