Physics 831 Practice Quiz #9 - Friday, Dec. 5

YOUR NAME:______________________________

1. N radioactive gas molecules are inserted into a gas at a time $t = 0$ and at a distance x_0 from a wall. The molecules then diffuse through time as determined by a diffusion constant D.

   (a) If the wall absorbs all molecules that touch it, find the density of gas molecules as a function of x, the distance from the wall, and t.

   (b) Repeat assuming that the molecules reflect off the wall.

2. An ideal gas of particles of mass m is initially at a temperature T_0, has zero collective velocity, and as far as one cares to look, the number density profile initially has an exponential profile in the x direction:
$$\rho(x, t = 0) = \rho_0 e^{-x/\lambda}.$$
   The gas then expands expands hyrodynamically.

   (a) What is the temperature, $T(x, t)$?

   (b) What is the density profile, $\rho(x, t)$?

3. Assume that early in the universe, at a proper time τ_0, that some massive dark matter particles of mass M froze out at a temperature, $T << M$, and ceased to interact. Assume that these particles had spin-0 and that they were chemically populated as if they had zero chemical potential. Further assume that the universe expanded such that the velocity gradient is consistent with a boost-invariant non-accelerating system,
$$\vec{v} = \frac{\vec{r}}{t}, \qquad \nabla \cdot v = \frac{3}{\tau}.$$

   (a) What was the density of particles at τ_0?

   (b) What was the phase-space density of particles at τ_0?

   (c) Assuming that the particles completely ceased to interact (no collisions or changes in their number), what is their density as a function of $\tau > \tau_0$?

   (d) What is their phase space density at $\vec{r} = 0$ as a function of τ?

   (e) How would the answer change if the particles were allowed to maintain kinetic equilibrium through collisions, but with their chemistry frozen?