Homework 1 (Due Tuesday, January 31st)

Let's get you warmed up with a few exercises on simple gases.

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1. A room (volume $V = 100\text{m}^3$) is initially at a chilly $T_i = 10^\circ$ C. After lighting a fire in the fireplace the temperature in the room rises to $T_f = 25^\circ$ C. The room is not air-tight so the initial and final pressures are one atmosphere. Taking the air to be an ideal gas with a heat capacity per molecule of $c_V = \frac{5}{2}k$, find the initial and final energies, U_i and U_f, for the air in the room.

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2. Consider n moles of an ideal gas undergoing an adiabatic process (i.e., Q constant). Show that PV^γ is constant, where $\gamma = c_P/c_V$ is the ratio of the ratio of the heat capacities per molecules. Note that for an ideal gas $C_P - C_V = Nk$.

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3. The equation of state for a hard sphere gas is

$$P = \frac{nRT}{V - bn}$$

where b is a constant. Note that we recover the ideal gas law when $b = 0$. As with an ideal gas, for the hard sphere gas the internal energy only depends on the temperature so $U = C_V T$ and $C_P - C_V = Nk$. If n moles of a hard sphere gas, initially at pressure P_0 and volume V_0, undergoes an adiabatic process then $P = f(V)$. Obtain an expression for the function $f(V)$.

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4. The Ruchhardt experiment is a classic method to measure $\gamma = c_P/c_V$ for an ideal gas. In the experiment a large bottle of volume V_0, filled with gas at atmospheric pressure P_0, is fitted with a stopper cork with a glass tube. In the tube is a small metal ball (radius r, density ρ) that fits snugly but moves freely (like a piston); at rest it is supported by the pressure in the bottle. When displaced a small distance from rest the ball moves up and down the tube with simple harmonic motion. Assuming that the process is adiabatic use the result obtained in Exercise 2 to find an expression for the oscillation frequency, f, in terms of γ and the other parameters in the experiment. [Hint: You should find that $f \propto \sqrt{r}$.]

Solve these problems yourself or in discussion with your classmates.

DO NOT TRY LOOKING UP THE SOLUTIONS ON THE INTERNET.
