

Physics 4311: Thermal Physics - Homework 3

due date: Tuesday, Feb 13, 2024, please upload your solution as a pdf on Canvas

Problem 1: Root-mean-square velocities at room temperature (10 points)

Calculate the root-mean-square velocities of various gases at room temperature.

- a) H₂.
- b) He.
- c) CO₂.

Problem 2: High-speed molecules (16 points)

Consider a two-dimensional ideal gas of molecules of mass m at temperature T .

- a) Write down the two-dimensional Maxwell velocity distribution $P(v_x, v_y)$
- b) Compute the root-mean-square velocity $\langle \vec{v}^2 \rangle^{1/2}$ in two dimensions.
- c) Find the probability of a molecule having a speed larger than twice the root-mean square velocity.
(Hint: Go to polar coordinates!)

Problem 3: Doppler broadening of spectral lines (14 points)

The atoms of an interstellar cloud (in thermal equilibrium at temperature T) emit light. The emission frequency of a particular element is ω_0 if the atom is at rest. Due to the thermal motion of the atoms, the observed frequencies are shifted (Doppler effect) to

$$\omega = \omega_0 \left(1 - \frac{v_x}{c} \right)$$

where v_x is the velocity component of the atom away from the detector.

- a) Calculate the average observed frequency $\langle \omega \rangle$.
- b) Find the width of the spectral line, i.e., the standard deviation σ_ω of the observed frequency.