

# Physics 4311: Thermal Physics - Homework 4

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due date: Tuesday, Feb 20, 2024, please upload your solution as a pdf on Canvas

## Problem 1: Mean free paths (10 points)

A diffuse cloud of neutral hydrogen atoms in space has a number density of  $500 \text{ cm}^{-3}$  and a temperature of 30K. (The hydrogen atom can be approximated as a sphere of radius  $0.53 \text{ \AA}$ )

- Find the collision cross section.
- Estimate the mean collision time.
- Estimate the mean free path.

## Problem 2: Pressure change due to effusion (15 points)

A box of volume  $V$  contains an ideal gas that is kept at temperature  $T$  by a thermostat. Its initial pressure is  $p_0$ . At time  $t = 0$ , a small hole of cross section area  $A$  is opened in the box, and gas starts escaping. (Assume that the hole is sufficiently small so that the gas in the box remains in equilibrium during the effusion process.)

- Derive a differential equation for the pressure  $p$  in the box as a function of the time  $t$  after opening the hole.
- Solve the differential equation and find  $p(t)$ .

## Problem 3: Exact differentials (15 points)

- Test whether the following differentials are exact.

$$du_a = 2x dx + dy$$

$$du_b = y dx$$

- If the differential is exact, calculate the indefinite integral.
- Check the dependence of the integral on the path of integration by explicitly integrating both differentials from point  $(x_i, y_i) = (0, 0)$  to  $(x_f, y_f) = (2, 2)$  on two different paths,  $(0, 0) \rightarrow (2, 0) \rightarrow (2, 2)$  and  $(0, 0) \rightarrow (0, 2) \rightarrow (2, 2)$ . Compare the results of the two paths and that of a calculation using the indefinite integral (if it exists).