**Homework Set 1: PH2202, THERMAL PHYSICS, SPRING 2021**

**Instructor: Arindam Kundagrami**

**TOTAL MARKS: Not Applicable, DUE: Finish by 19 February 2021 (well before mid-sem, so that we can have discussion). For practice.**

**THESE ASSIGNMENT PROBLEMS WILL BE DISCUSSED IN CLASS AND TUTORIALS. PRACTISE AND SOLVE THEM ON YOUR OWN. IT WILL HELP YOU BOTH UNDERSTAND THE SUBJECT AND DO WELL IN EXAMS.**

1. Do all the derivations which are done in class and are included in the course notes in details, on your own.

2. The number density of molecules with $x$-component of velocities between $u$ to $u + du$ is given by

$$dn_u = nf(u)du = na\exp(-u^2/\alpha^2)du$$

,

where, $n$ is the number density, and $a, \alpha$ are constants.

First, show independently that the expression of pressure can be written as

$$p = 2mn\int_0^\infty f(u)u^2du.$$

Further, from theory of probability and ideal gas law find the expressions of constants $a$ and $\alpha$ as functions of $m, T$.

3. Find the following quantities for a two-dimensional ideal gas: a) number of impacts in unit time on unit length (which was unit area for the three-dimensional gas), b) pressure (that is defined as force per unit length in the boundary), c) the Maxwellian velocity distribution expression, d) average (mean) speed, e) Root-Mean-Square (RMS) speed, f) most probable speed, g) energy distribution.

4. The mean kinetic energy of a molecule of an ideal gas at $27^o$ C is $8.0 \times 10^{-14}$ erg. Calculate the number density of molecules of this gas at this temperature and at a pressure

of 40 mm of mercury.

5. If molecular diameter of hydrogen is $1.9 \times 10^{-8}$ cm., find the number of collisions encountered by a hydrogen molecule in 1 second. The gas is in room temperature and under standard atomospheric pressure.

6. A thin-walled container of volume $V$, kept at a constant temperature, contains a gas which slowly leaks out through a small hole of area $A$. The outside pressure is comparatively low enough so that back-leakage into the vessel is negligible. Find the time required for the pressure in the vessel to decrease to $1/e$ times its original value. Express your answer as a function of $A, V$ and the mean velocity $\bar{c}$.

7. Show that if the RMS speed be taken as unit of speed for gas molecules, the probability distribution of speed becomes independent of temperature.

8. Find the ratio of the number of molecules with speed between $c_r$ to $c_r + dc$, where $c_r$ is the RMS speed to number of molecules with speed between $c_m$ to $c_m + dc$, where $c_m$ is the most probable speed.

9. Two thermally insulated containers of volume $V_1 = 1$ litre and $V_2 = 3$ litre, respectively, are connected by a pipe with a tap. Before opening the tap, the first container has nitrogen at temperature $T_1$=273 K and pressure $p_1$= 0.5 atmosphere, and the second container has argon at temperature $T_2$=373 K and pressure $p_2$= 1.5 atmosphere. Find the temperature and pressure of the mixture when equilibrium is established after the tap is open.

10. Assuming Maxwell's distribution of velocities, find the total kinetic energy $E_{tot}(n, T, m)$ of all molecules of an ideal gas impacting unit area of container in unit time. The symbols have usual meaning.

11. If the mean molecular diameter of air molecules be $3 \times 10^{-10}$ m, to what pressure must a container be de-pressurized so that the mean free path of the gas at the freezing point of water exceeds one-tenth of a meter?