Physics 180E Homework #1

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Problem 0.1.

(a) According to the ideal gas law,

$$\frac{N}{V} = \frac{P}{kT} = \frac{P}{(300\,\mathrm{K})\,(1.381 \times 10^{-23}\,\mathrm{J/K})} = \frac{P}{4.142 \times 10^{-21}\,\mathrm{J}}.$$

When the pressure is 1 Torr, that works out to

$$\frac{N}{V} = \frac{1\,\mathrm{Torr}}{4.142 \times 10^{-21}\,\mathrm{J}} \cdot \frac{133.32\,\mathrm{Pa}}{\mathrm{Torr}} = 3.219 \times 10^{22}\,\mathrm{m}^{-3}.$$

So at 1 Torr, there are 3.219×10^{22} atoms per meter cubed. At 100 mTorr, there are 3.219×10^{21} atoms per meter cubed. At 10 mTorr, there are 3.219×10^{20} atoms per meter cubed.

(b)

(c)

(d)

Problem 0.2.

(a)

(b)

Problem 0.3.

(a)

(b)

(c)

(d)

(e)

Problem 0.4.

PHYSICS 180E, WINTER 2025

HOMEWORK 1
(DUE WEDNESDAY JAN. 17 BY MIDNIGHT ON GRADESCOPE)

1. We will be creating plasmas out of low-density gases in a vacuum chamber. Answer the following for room-temperature Argon gas at three pressures: 10 mTorr, 100 mTorr, and 1 Torr.

   (a) What is the number density (atoms per unit volume)?

   (b) What is the mean-free-path for collisions between neutral atoms? You can assume that the cross-section is $\sigma \sim 10^{-15}$ cm^{-2}.

   (c) What is the collision frequency?

   (d) If instead the fill gas was Helium, would any of your answers change? If so, why?

2. Now consider an electron having 100 eV of kinetic energy moving through a 100 mTorr room-temperature Argon gas.

   (a) Assuming the electron-neutral collision cross section is also $\sim 10^{-15}$ cm^{-2}, what is the mean-free-path of electron in the gas?

   (b) What is the collision frequency?

3. Plasma physicists typically quote temperature in electron volts rather than Kelvin. When electron volts (an energy unit) are used in this way, the quantity being quoted is:

$$T_{eV} = \frac{k_B T}{e}$$

   where T_{eV} is the "temperature" in electron volts, k_B is Boltzmann?s constant, and e is the elementary charge.

   (a) What is the temperature in Kelvin associated with 1 eV?

   (b) What is room temperature stated in electron volts?

   (c) What is the temperature in Kelvin at the center of the sun ($T_{eV} \sim 1$ keV)?

   (d) What is the temperature in Kelvin in the hottest tokamak plasmas on record ($T_{eV} \sim 50$ keV)?

   (e) What is the thermal velocity associated with a Maxwellian distribution of electrons with a temperature of 1 eV?

4. Look up and write down the first ionization potentials for the following gases: Helium, Neon, Argon, and Nitrogen. We will be making plasmas out of these gases using electron-impact ionization.