Chemical Engineering
Principles of Plasma Processing
UCLA, Spring 2004

Due: April 22, 2004

Note: The initial problems ask you to derive certain formulas given to you so that you do not have to take them on faith. Please work these out yourself and do not copy previous answers. You will be graded on effort.

1. Derive the Boltzmann relation from the momentum conservation equation. Explain your assumptions.

2. The probability of finding a molecule with a particular speed in a low pressure gas follows the Maxwell-Boltzmann Distribution function:

$$f(v) = \left[\frac{m}{2\pi kT}\right]^{3/2} \exp\left[-\frac{mv^2}{2kT}\right] 4\pi v^2$$

Show that:

(1) the root-mean-square speed of the gas molecule is: $\overline{v_{rms}} = \left(\int_o^\infty v^2 f(v) dv\right)^{1/2} = \sqrt{\frac{3kT}{m}}$.

(2) the average one way particle flux is: $\Gamma = \frac{n\bar{v}}{4}$.

(3) the ideal gas law: p = nkT

3. The 1-D Boltzmann Transport Equation for electrons is: $\frac{\partial f_e}{\partial t} + v_z \frac{\partial f_e}{\partial z} - \frac{eE_z}{m}\frac{\partial f_e}{\partial v_z} = \left.\frac{\partial f_e}{\partial t}\right|_c$

Use $f_e = f_e^i + \frac{v_z}{v}\overrightarrow{f_e^a}$, show that:

$$\frac{\partial f_e^i}{\partial t} + \cos\varphi \frac{\partial \overrightarrow{f_e^a}}{\partial t} + v\cos\varphi \frac{\partial f_e^i}{\partial z} + v\cos\varphi^2 \frac{\partial \overrightarrow{f_e^a}}{\partial z} - \frac{eE_z}{m}\cos\varphi \frac{\partial f_e^i}{\partial v} - \frac{eE_z}{m}\left[\frac{\overrightarrow{f_e^a}}{v} + v\frac{\partial}{\partial v}\left(\frac{\overrightarrow{f_e^a}}{v}\right)\cos\varphi^2\right] = \left.\frac{\partial f_e}{\partial t}\right|_c$$

Hint: For spherical coordinates: $v_z = v \cdot \cos\varphi$ and $\frac{\partial}{\partial v_z} = \cos\varphi \cdot \frac{\partial}{\partial v} - \frac{\sin\varphi}{v}\frac{\partial}{\partial \varphi}$

4. Discuss what differentiates the MBD, Margenau, and Druyvestryn distributions.

5. Determine the gas flow regimes and calculate the mean free paths of the N_2 gas molecules at (1) 0.1 mtorr, 300K and (2) 10 torr, 700K. Assume the characteristic length of the process chamber is 5 cm.