EE507 – Plasma Physics and Applications

Solutions to homework #4

2) a) $\sigma = 6\pi a_0^2 = 5.29\times10^{-20}\ m^2$

$$E = \frac{1}{2} m v^2 \Rightarrow v = \sqrt{\frac{2E}{m}} = 8.4\times10^5\ m/sec$$

$$\langle \sigma v \rangle \cong \sigma v = 4.5\times10^{-14}\ m^3/sec$$

$$D_e = \frac{kT_e}{m\nu}$$

$$\nu = n_g \langle \sigma v \rangle \cong n_g \sigma v$$

$$n_g = 3.24\times10^{19}\ \frac{1}{\ell} = 3.24\times10^{22}\ m^{-3}$$

$$\nu \cong 1.46\times10^{8}\ 1/sec$$

$$D_e = \frac{2\times1.6\times10^{-19}}{9\times10^{-31}\ 1.46\times10^{8}} = 2.44\times10^{2}\ m^2/sec$$

b) $J = \mu_e n e E \Rightarrow E = \dfrac{J}{\mu_e n e}$

$$\mu_e = \frac{e D_e}{kT_e} = \frac{1.6\times10^{-19}\ 2.44\times10^{2}}{2\ 1.6\times10^{-19}} = 1.22\times10^{2}\ \frac{m^2}{V\text{-}sec}$$

$$E = \frac{2000}{1.22\times10^{2}\ 10^{16}\ 1.6\times10^{-19}} = 1.02\times10^{4}\ V/m$$

3) IF THE PLASMA DECAYS BY BOTH DIFFUSION AND RECOMBINATION THEN

$$\frac{\partial n}{\partial t} = \underbrace{D\nabla^2 n}_{\text{RATE OF LOSS BY DIFFUSION}} - \underbrace{\alpha n^2}_{\text{RATE OF LOSS BY RECOMB.}}$$

FOR A PLASMA SLAB WE KNOW THAT

$$n = n_0 \cos\frac{\pi x}{2L}$$

SO

$$D\nabla^2 n = -D\,\underbrace{n_0 \left(\frac{\pi}{2L}\right)^2 \cos\frac{\pi x}{2L}}_{n} = -D\,n\left(\frac{\pi}{2L}\right)^2 = -\alpha n^2$$

$$\Rightarrow \quad n = \frac{D}{\alpha}\left(\frac{\pi}{2L}\right)^2 = \frac{0.4}{10^{-15}}\left(\frac{\pi}{2\ 0.03}\right)^2 = 1.097 \times 10^{18}\ m^{-3}$$ 2/

4) $$\frac{1}{n(t)} = \frac{1}{n_0} + \alpha t$$

$$\Rightarrow \alpha = \frac{1}{t}\left(\frac{1}{n(t)} - \frac{1}{n_0}\right) = \frac{1}{10^{-2}}\left(\frac{2}{10^{20}} - \frac{1}{10^{20}}\right) = 1 \times 10^{-18}\ \frac{m^3}{sec}$$

5) $$\frac{\partial n}{\partial t} = D\nabla^2 n + G_0 = 0 \quad \text{(STEADY STATE)}$$

$$\nabla^2 n = \frac{d^2 n}{dx^2} = -\frac{G_0}{D} \quad \Rightarrow n(x) = Ax^2 + Bx + C$$

$$\frac{dn}{dx} = 2Ax$$

$$\frac{d^2 n}{dx^2} = 2A = -\frac{G_0}{D} \Rightarrow A = -\frac{G_0}{2D}$$

$$\left.\begin{aligned} n\left(\tfrac{l}{2}\right) &= -\frac{G_0}{2D}\frac{l^2}{4} + B\frac{l}{2} + C \\ n\left(-\tfrac{l}{2}\right) &= -\frac{G_0}{2D}\frac{l^2}{4} - B\frac{l}{2} + C \end{aligned}\right\} B = 0 \ \& \ C = \frac{G_0}{2D}\frac{l^2}{4}$$

$$n(x) = -\frac{G_0}{2D}x^2 + \frac{G_0}{2D}\frac{l^2}{4} = \frac{G_0}{2D}\left(\frac{l^2}{4} - x^2\right)$$

@ $x = 0$ $\quad n(0) = n_0 = \dfrac{G_0 l^2}{8D}$

6) SEE NOTES