NPRE 321: Introduction to Plasmas and their Applications

Homework 3.

Constants

$m_e = 9.11\times10^{-31}$ kg

$u = 1.66\times10\text{-}27$ kg

$m_H = 1.673\times10^{-27}$ kg

$c = 2.998\times10^{8}$ m s^{-1}

$e = 1.602\times10^{-19}$ C or J/eV

$k_B = 1.38\times10^{-23}$ m^{2}kg s^{-2}K^{-1}

$N_{AV} = 6.022\times10^{23}$ mole^{-1}

$\mu_0 = 4\pi\times10^{-7}$ m kg s^{-2}A^{-2}

$\varepsilon_0 = 8.854\times10^{-12}$ m^{-3}kg^{-1}s^{4}A^2

H = 1.008000u

D = 2.014102u

T = 3.016049u

^{4}***He*** = 4.002602u

n = 1.008665u

$N_{tor} = 40$

$N_{hel} = 4$

1 eV = 11604 K

Make sure to show all working including any diagrams

All the following questions relate to this single system. A DC cathodic arc is a plasma device that is used to deposit conducting material onto a substrate. It is one way to deposit material onto a surface. The DC arc is shaped like a ¼ torus (doughnut). It has the equivalent to a toroidal magnetic field. It has a radius of curvature R_0 = 50 cm and a vessel radius of a = 10 cm. The magnetic field on axis is 30 mT and the plasma is a metallic plasma made from titanium (Ti). Assume that the titanium is singly ionized. The electron temperature is T_e = 10 eV and the ions are close to room temperature (27 ^{o}C). At one end is the source of the plasma and the other end is a substrate plate with a -1 kV bias placed upon it. The plasma density is $n_e = 2\times10^{18}$ m^{-3}.

Question 1: Draw what the DC cathodic arc would look like? Make sure to include, vacuum vessel, Magnetic coils, magnetic field and gradient, plasma and substrate with bias as well as other features.

(10 Marks)

Question 2: What are the high field and low field values of the magnetic field and what is the magnetic field gradient ∇B?

(10 marks)

Question 3: Calculate the average velocity of the electrons and ions.

(10 marks)

Question 4: What are the starting parallel and perpendicular velocities of the electrons and ions?

(10 marks)

Question 5: Assuming no drifts initially, calculate how much time it takes for the ions and electrons to reach the substrate?

(10 Marks)

Question 6: Calculate the plasma and cyclotron frequencies (in Hz) and Larmor radii for the electrons and ions.

(10 marks)

Question 7: Calculate the grad-B drift, $v_{\nabla B}$, is. There are two ways this can be done. Calculate and compare using the two methods.

(10 marks)

Question 8: Calculate the curvature drift, v_{R_c}, for the electrons and ions. Add this with the grad-B drift to get the total drift the ions and electrons will experience.

(10 marks)

Question 9: Using the time you determined in question 5 and the velocity of ∇B, drift. How far will the particles travel? Will they still reach the end of the substrate or hit the wall?

(10 marks)

Question 10: Write at least ½ a page but not more than a page on the following. At the substrate what will happen to each of the species? What energy will the electrons and ions reach the substrate? Discuss and use any equations to back up your argument.

(10 marks)