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SHEATH AND PRESHEATH IN A DIVERGING MAGNETIC FIELD WITH VOLUME PRODUCED NEGATIVE IONS

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Abstract

In different applications of plasma-surface interactions, If a magnetic field is not uniform, it is very important to study how the plasma sheath and presheath work together. For a long time, scientists have been interested in how to model things like sheaths, both from a theoretical and practical point of view. In ion-ion plasmas, there are no electrons in them, so they are made entirely of good and bad ions. In reality, only a very small amount of electrons can be found if the main negative charge carriers stay negative ions. This is true even if there are a lot of electrons. As you can see, these plasmas have been looked at both in the lab and in class. As you look at the field lines, it can be hard to tell if there is a diverging or open magnetic field. In this case, we use a computer to show how plasma flows to a solid wall without colliding with it. This means it doesn't matter how strong the electrostatic force is at the boundary wall if it doesn't stop particles from moving there. Instead, at the presheath, the mirror force is the main force, and it pushes all charged particles toward the boundary wall, so they all go there. So, the negative ions follow the field lines into the sheath, and then they reflect back at a place where the mirror force and electrostatic force work together are equal.

Keywords: Sheath, presheath, magnetic, volume, negative, ion, etc

1. INTRODUCTION

In different applications of plasma-surface interactions, the plasma sheaths and their presheaths are very important to study when there is a magnetic field that isn't the same all over to do. Researchers have been interested in sheath-related modelling for a long time, both from a theoretical and practical point of view. People who work with tokamaks, mirror machines, and systems that use important to think about how the electrostatic potential of lines in a diverging field affects how much energy particles have when they hit a surface that is in contact with the plasma. For the first time, Tonks and Langmuir made a kinetic model for a plasma that didn't get hit by other things. It was the first time that they used a cold ion source to find out how much potential there was. These people came up with a way to calculate how the electrostatic potential changes in the pre-sheath region for different shapes. They came up with a way to figure out how this happened.Harrison and Thompson found a way to solve the plasma equation for collisionless plasma that is in a planar shape. Self worked out the Poisson's equation for both the presheath and the sheath regions, which were only for cold ions. When Emmert et al. looked at this problem with warm ions, they thought about an ion source with a certain temperature that made a Maxwellian distribution function for the ions. Nobody thought about the length of Debye, so they didn't know what to expect looked into how the electrostatic potential was created from the bulk plasma to the sheath by solving an integro differential equation that didn't make any assumptions about the Debye length. The next time Robertson looked into the properties he made the presheath and the sheath for heated ions, he used a Maxwellian source to do this.

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1.1 Particle-in-cell simulation of sheath and presheath in ion-ion plasmas

Ion-ion plasmas, there are no electrons in them, so they are made entirely of good and bad ions. In reality, only a very small amount of electrons can be found if the main negative charge carriers stay negative ions. This is true even if there are a lot of electrons. As you can see, these plasmas have been looked at both in the lab and in class. A type of plasma called an ion-ion plasma can be made after pulsed discharges in electronegative plasmas, electron beams, magnetic filtering of electronegative plasmas, and so on. There are many uses for ion-ion plasmas. Kanakasabapathy and Walton have shown that when low-frequency sinusoidal bias is used to get positive and negative ions out of ion-ion plasma at the same rate, it works the same for both types of ions, too. This could be useful in the processing of materials so that microelectronic devices don't get charged up. All of the things that use them, like negative ion sources or dusty plasma, like them. Ion-ion plasmas are good for these things because they make the air cleaner. Last but not least, Chabert says that plasmas could be a good way to get around in space. As well as Midha et al., Midha and Economou and Midha used a time-dependent fluid model to look at how plasmas move when they have an rf and DC voltage on them. In this case, they found that the structure of the sheath was very different from the structure of normal electron-ion plasmas. Sheath size and whether or not there was a presheath were not looked into very much. Sheath, presheath, and making extraction grids for ion beams are all important things to think about. This letter talks about a particle-in-cell (PIC) simulation that works. In order to study ion-ion plasmas, no assumptions are made about how the energy is spread out. Under the influence of a dc bias, Childlaw type sheaths are formed in a few microseconds, which is very fast. An ion takes this long to move from one electrode to the other. This is how long that takes. The charged species that are at one of the electrodes are sped up to the sound speed by a presheath. There are two main things this could mean: This means that it is faster to have ion-ion plasma at the start of a sheath than to have the average speed of ion-ion plasma in one direction. This makes the sheath size, which is critical from an applied standpoint.

2. REVIEW OF THE LITERATURE

Rakesh Moulick, Sayan Adhikari, and Kalyan Goswami (2019) In collisional and magnetised low-pressure plasma, the formation of a plasma sheath is looked at to see if it can happen. In one place, the magnetic field is bent in a certain way. When the model is used with a wide range of magnetic field strengths and tilting angles, it creates plasma profiles. Sheath entry speeds should be set for all three components of ion speed, not just one. This is shown in the magnetised case (which is directed along the sheath). Net velocity of ion increases to the speed of the characteristic ion when there are no collisions between the ions (Bohm speed). This, in turn, is found to keep the ion density's change in monotony. With a constant ionising frequency, ionisation is taken into account. For low pressure magnetic plasma, comments are made about the thickness of the sheath and how well the Debye sheath is held on at a low angle.

Ananya Phukan, Kalyan Goswami, and Pranjal J. Bhuyan (2014) an analytical-numerical technique is used to investigate the Near the wall, a lot of plasma with many different types of molecules made negative ions when the magnetic field that changed from side to side. A constant source of negative ions, as well as positive ions at a certain temperature and Boltzmann electrons at a certain temperature, are assumed to be in the plasma at all times. Some people think that an open magnetic field helps the particles move in the right direction. It's strongest in the field and gets weaker as it nears the walls, so the field is thought to help the particles move. To look at the possible profiles, an analytical approach is used to make the one-dimensional (1D) Poisson equation, which is then solved numerically. People looked at how (a) the rate at which negative ions formed, (b) the the temperature of the negative ions changed, it also changed the magnetic field profile, which is what we call the magnetic field pattern When there are a lot of negative ions near the wall, there is a lot of potential there. If you have a short Debye Length (D), the presence of negative ions also makes the plasma less charged area.

Sejal Shah and Mainak Bandyopadhyay (2010) Step one in a high current negative ion source, negative ions are being made on the outside of the body. People should do this first. Plasma is shown in this article, and it shows how it works sheath near a metallic surface changes when negative ions are made on the surface. Negative ions on the surface can change the electric potential at the edge of an electronegative plasma, which is what the Bohm criterion says is true. This abstract's Bibtex entry is the best way to put this abstract in (see Preferences) In the same way: can be found here: Return: Authors Title Abstract Text Results of the Query Items beginning with a number should be returned. Database Query Form: ArXiv e-prints in Astronomy and Physics.

Meige, Leray, Raimbault, and Chabert (2008) a comprehensive According to Meige, Leray, Raimbault, and Chabert, a particles in cells are used to look at electron-free plasmas when a dc bias voltage is used to look at positive and negative ions in them. The process of making high-voltage sheaths that look like Child-law sheaths takes only a few microseconds, which is how long it takes for an ion to move after a dc voltage is applied. That's not all: It has been shown that one of the electrodes has a Bohm criterion, which means that ions that have been collected at one of them can be moved to sound speed before they enter the sheath. I look at it from a practical point of view standpoint, these results in smaller sheaths than one may assume.

3. OBJECTIVES

- To study Particle-in-cell simulation of sheath and presheath in ion-ion plasmas.
- To evaluate Numerical solution and normalization.

4. RESEARCH METHODOLOGY

In the presence of a diverging or open a magnetic field, where the field lines appear to split in the direction of the wall, we use a computer to model collision less plasma flow to a solid wall. Hydrogen plasma comprising positive ions, negative ions, and electrons was considered.

4.1 Theoretical formulation

Figure 1 shows A diagram axisymmetric magnetic field lines on the top of the model with the model The electric potential (x) and magnetic field B(x) are thought to be equal around x = 0 and fall away from the wall at the same rate. They are called "zero" and "B0" when they happen at the centre (x = zero). In this case, we think that the walls are completely absorbing and that the floor isn't absorbing at all. electrically floating.

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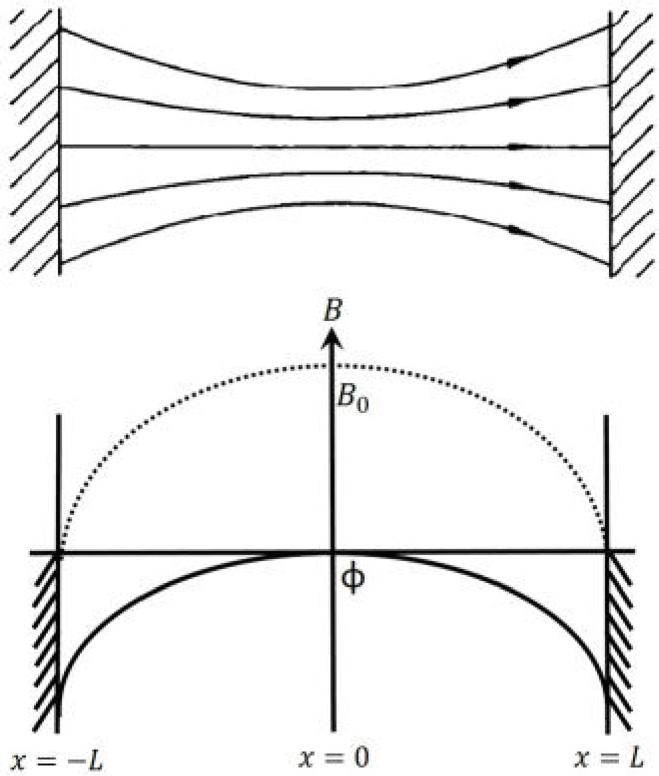

Figure 1: Schematic of the model

Speed can be divided into two parts in a magnetic field: one that goes along the field and one that goes against it (v||). This way, you can figure out how fast an ion is going (v). There are two things that move the ions: energy and magnetic moment. They have different kinds of energy, and this is what makes them positive or negative can be calculated as follows:

$$\varepsilon = 1/2 \text{ mi } (v_{\|}^{2}k + v^{2}_{\perp}) + q\varphi(x) \quad (1)$$

$$\varepsilon_{-} = 1/2 \text{ mi} - (v_{\|}^{2}k + v^{2}_{\perp}) - q\varphi(x) \quad (2)$$

Where the masses of the ions are mi and mi, There are two kinds of velocities: one that goes along the magnetic field and one that goes against it. The charge of both ions is = miv 2/2B(x) and = miv 2/2B(x), where B(x) is the magnetic field intensity at X. radial dependence is not taken into account, and gyromotion is integrated out.

5. DISCUSSION AND RESULT

5.1 Numerical solution and normalization

Eqn.3 is solved by scaling the variables with appropriate scaling parameters and normalizing them. The following are the normalized parameters utilized in this study:

$$\frac{d^2\phi}{dx^2} = \frac{n_0 e}{\varepsilon_0}\exp\left(\frac{e\phi(x)}{kT_e}\right) - \frac{q}{\varepsilon_0}S_0\left(\frac{\pi m_i}{2kT_i}\right)^{1/2}\int_0^L h(x')I(x,x')dx' + \frac{q}{\varepsilon_0}S_{0-}\left(\frac{\pi m_{i-}}{2kT_{i-}}\right)^{1/2}\int_0^L h(x')I_-(x,x')dx' \quad (3)$$

$$\eta = \frac{-e\phi}{kT_e},\quad s = \frac{x}{L},\quad \tau = \frac{T_e}{T_i},\quad ,\tau_- = \frac{T_e}{T_{i-}},\quad Z = \frac{q}{e},\quad R = \frac{B_0}{B(x)}$$

$$M = \frac{m_i}{m_e} = \frac{m_{i-}}{m_e},\quad N_i = \frac{n_i}{n_0},\quad N_{ni} = \frac{n_{i-}}{n_0},\quad \xi^2 = \left({}^{\lambda_D}/_{L}\right)^2/\exp\left({}^{e\phi_w}/_{kT_e}\right)$$

The net positive current must equal the net negative current on the wall with a floating potential. This condition can be expressed as follows:

$$ZeS_0L = en_0\left(\frac{kT_e}{2\pi m_e}\right)^{1/2} exp\left(\frac{e\phi_w}{kT_e}\right) + ZeS_{0-}L \quad (4)$$

Where the left hand side represents the positive ion current density at the wall, and the right hand side represents the electron current density and negative ion current density at the wall, respectively.

The amount of negative ion present in the system is quantified by the parameter $\beta(= S_{0-}/S_0)$. The present conservation equation yields the average source strengths S_0 and S_{0-} (Eqn.3).

$$S_0 = \frac{n_0}{ZL(1-\beta)}\left(\frac{kT_e}{2\pi m_e}\right)^{1/2}\exp\left(\frac{e\phi_w}{kT_e}\right) \quad (5)$$

$$S_{0-} = \frac{n_0\beta}{ZL(1-\beta)}\left(\frac{kT_e}{2\pi m_e}\right)^{1/2}\exp\left(\frac{e\phi_w}{kT_e}\right) \quad (6)$$

The default parameters are as follows: kT_e = 1eV, kTi = kTi− = 0.05eV, λ_D/L = 0.05, M = 1836. The mirror ratio (R) is calculated as a function of potential, assuming that the electric potential and magnetic field intensity profiles follow a monotonic variation in space.

By adjusting, we were able to obtain the results for various magnetic field profiles.

$$R = \exp(\alpha\,\eta) \quad (7)$$

$\alpha = 0$ denotes a homogeneous higher values of show that the magnetic field structure for the model field is less symmetrical than the real field.

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Figure 2 shows how the total density of ions changes over space for different magnetic field profiles (i.e. = 0, = 0).3 and α = 0.6). The profiles for positive ion density, total negatively charged particle density (which includes electrons and negative ions), and space charge (Q_{sp}) developed at the sheath are shown in this figure. The you look at the normalised distance scale, you can see that the bulk and the boundary wall of the plasma are shown by coordinates s = 0 and s = 1. All charged particles move faster because of the mirror force towards the wall as the magnetic field gradient increases (more diverging), causing the density to fall quicker as a result, with higher values of, the space charge deposition caused by the difference between positively and negatively charged particles in the sheath drops significantly. With rising value of, the sheath edge, which is governed by the quasineutrality breaking point, pushes towards the bulk α. It means that the negative floating potential created at the wall is not adequately veiled by the positive ions present near the wall, and as an effect, the sheath expands when the mirror force is at its strongest. Furthermore, as the magnetic field gradient increases, the density in the presheath region drops fast, whereas the density decline in the sheath region slows down.

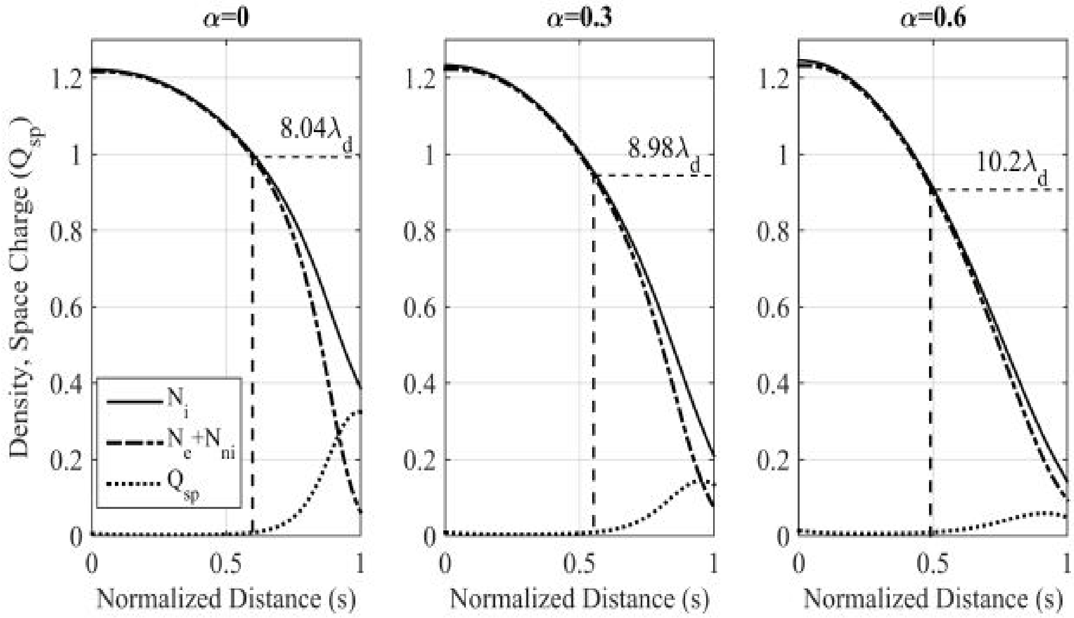

Figure 2: Total ion density and space charge variations in space for different values of α

The density profile of negative ions is shown in Fig. 3 for various values of α. It changes the density of negative ions as you move across the plasma volume because of the forces you feel when you move along field lines. There is the most negative ion density in the presheath. If you have a lot of magnetic fields, this density peak gets more sharp and moves closer to the bulk. The growth of the mirror force at higher values of is what makes this happen. It has been shown in the past that cold negative ions with temperatures around 0.026 eV don't get into the sheath at all. It's not that simple, though. It's only possible to detect a few negative ions in the area of a "sheath." The rest are reflected at a point where both the mirror force and the electrostatic force work together. This is called a "electromagnetic point." are equal. They can get past electrostatic resistance and reach the wall by

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following the field lines at greater magnetic field gradients (= 0.6). Since there are more negative ions close to the wall when there is more of them, the density near the wall is slightly higher.

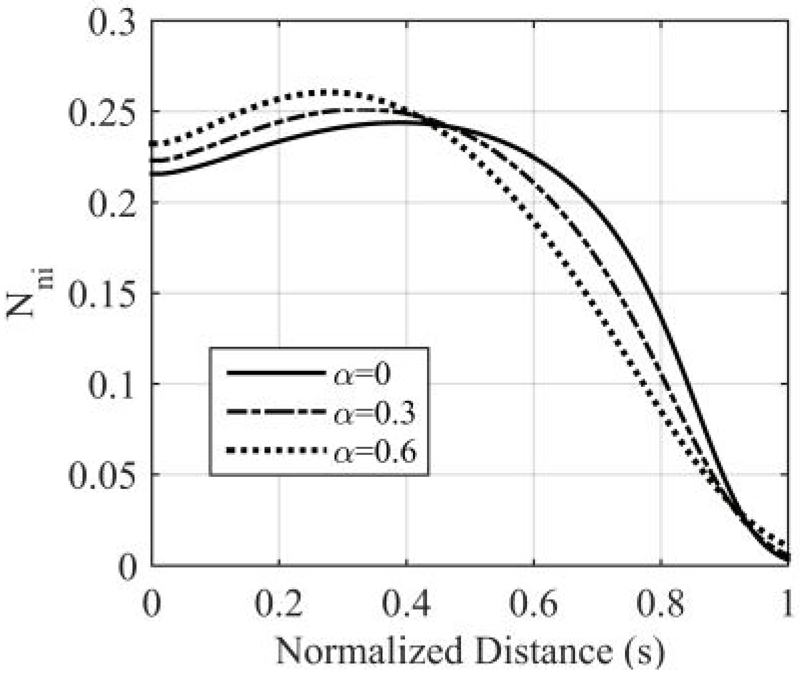

Figure 3: Spatial variation of the negative ion density for various magnetic field profiles

Figure 4 depicts The relationship between the density of electrons and the shape of the magnetic field. There is a way to keep things quasi-neutral in the presheath. The electron density drops faster for bigger values. Outside of the sheath, this changes. In the lower the value of, the electron density quickly drops.

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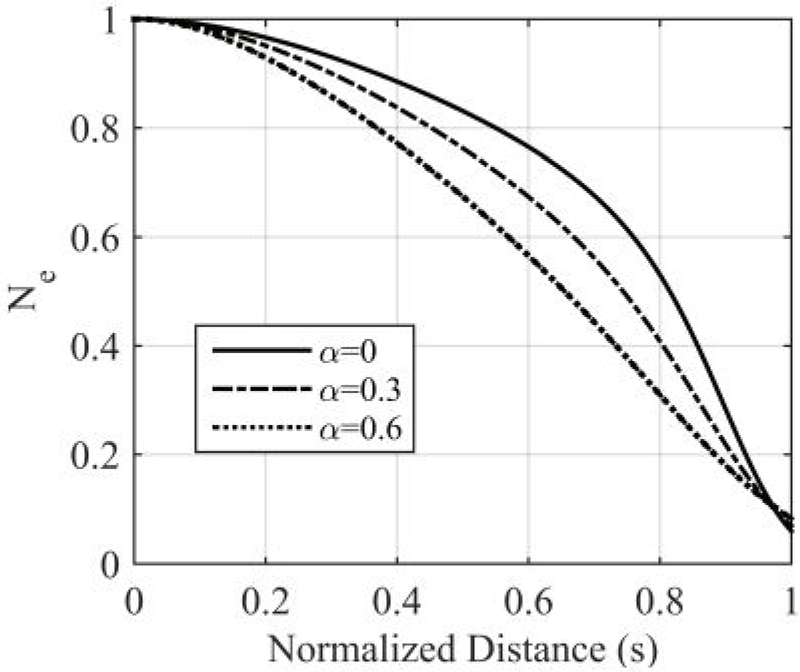

Figure 4: Electron density variation in space for various magnetic field profiles

In this study, we numerically solved the collisionless plasma with negative ions in the plasma-sheath equation presence of a diverging magnetic field. We looked at how the presheat and sheath potentials were created, as well as how they changed. When the magnetic field gradient goes up, the amount of space charge in the sheath drops dramatically, which lowers the electric field and stops the Debye shielding effect.

6. CONCLUSION

Unless the It is strong enough to keep things from moving. It is the main force at the presheath, and it moves all charged particles in that direction. They follow the field lines until they reach a point where they can be reflected back at the same place that they came from. That's where they go. Magnetic fields that are open or diverge can make the field lines look like they are going the same way as they do on a wall. is simulated numerically in this work. Positive ions, negative ions, and electrons were all thought about in hydrogen plasma. By giving each type of ion a distribution function and assuming that they all start out at the same speed, you can make a model that doesn't have collisions. According to the rate of ionisation, ions are made all over the volume. The ion sources within the plasma are specified to maintain a constant state.

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