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Charge Transport in Magnetized Plasma

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Abstract

The plasma source can restrict the motion of charges that are localizing in the non equilibrium distribution of charge energy and reducing the electrons transport across magnetic field . The electrons & ions motion are controlled by ambipolar electric field and charge–atom collision . The source density for a given electron temperature and a given ion are considered to evaluate the diffusion coefficient . The ambipolar diffusion coefficient and the cross field diffusion coefficient for charge transfer are calculated through magnetized plasma in a uniform magnetic field , and an approximation ambipolar diffusion coefficient is evaluated. The result, showes how the diffusion process is gradually imbedded as the properties of the plasma.

Key words :- Change transport , monetized plasma , diffusion coefficient

Introduction

The transfer of wave function energy towards the long region and the formation of longe scale structures is a result of the well–known inverse cascade in two dimensional and quasi two – dimensional fluids [1] . A complete understanding of charge transport is important for characterizing materials used in the components which are directly exposed to the charge (proton) isotope plasma [2] . The source of electron transport in magnetized plasmas which can be a major obstacle in the way toward particles nuclear fusion power . The observed electron energy transport is much larger than are would expect from diffusion process due to coulomb collisions [3] .The diffusion has important technological implications in micro electronics [4] . Coalitional cross field transport due to electric or magnetic field asymmetries is important in many neutral and non neutral plasma confinement devices [5] . It is the purpose of this paper to give transport description of diffusion across magnetic field in plasma source .

Theory

Transport in the discharge is controlled by equilibrium magnetic field , ambipolar electric field , and ion – atom collisions [4 - 5] .

For a plasma with a single species of singly charged ions , the am bipolar diffusion coefficient in a weakly ionized system of sufficient size is given by [6] .

$$D = \frac{c_s\,(1+T_i/T_e)}{n_n\,(\sigma_e\sqrt{m_e/m_i}+\sigma_i\sqrt{T_i/T_e}} \qquad \ldots\ldots\ 1$$

Where n_n is the neutral gas density , σ_e and σ_i are the total scattering cross section with neutrals for electrons and ions respectively , m_e is the electron mass , m_i is the ion mass , T_e is the electron temperature , T_i is the ion temperature and c_s is the ion sound speed [7] .is given by [6 – 7] .

$$c_s = \sqrt{k\,T_e/m_i} \qquad \text{…… (2)}$$

The cross section for electrons or ions are given [8]

$$\sigma = 1/n\lambda \qquad \text{…… (3)}$$

Where λ is the collisonal mean free path .

The ion – atom collision frequency is given by [6] .

$$\upsilon = n_o\, v\,(\sigma_e + \sigma_i) \qquad \text{….. (4)}$$

When n_o is the gasses density and v is the ion velocity is given by

$$v_i = \sqrt{\frac{2T_i}{m_i}}$$

However when the electron – ion mass ratio << T_e/T_i and small value that can be ignored in Equ(1) and results .

$$D = \frac{c_s}{n_n\ \ \sigma_i}\sqrt{\frac{T_e}{T_i}} \qquad \text{…… (5)}$$

The magnetic field can inhibit electron motion perpendicular to the magnetic field lines described by cross field diffusion coefficient D_ρ and given [7] .

$$D_\rho = \frac{n_n\ \ \sigma_e\ \ v_{th}}{2}\,\rho_e^2 \qquad \text{…… (6)}$$

Here v_{th} is the electron thermal speed and ρ_e is the electron gyro radius is given by [6]

$$\rho_e = \frac{v}{w} = \frac{n_o \ v \ (\sigma_e + \sigma_i)}{w} \qquad \text{......} \ (7)$$

Whene the plasma frequency is given by [9] .

$$W_p = \frac{eB}{m_i} \qquad \text{.....} \ (8)$$

Herne B is the static magnetic field strength

Results

In order to determine the diffusion coefficient of charge transport in magnetized plasma theoretically using the equation (1) , one must initially evaluate the values of the ions sound speed c_s form equation (2) for a variety ions Hydrogen , Argon , and Nitrogen where the energies of electrons kT_e taken between (1 to 2.4) ev [10] . The values of mass of ions are $m_H = 1.67826*10^{-27}$, $m_{ar}= 2.67*10^{-26}$ kg , and $m_n = 2.5*10^{-26}$ kg were extracted from the literature [11-12] .

Amore general expression equation (2) was applied to evaluate the sound speed of Argon , Hydrogen , and Nitrogen cons ions with masses of these ions , the results have been summarized in table (1) .

We use the results of sound speed ions c_s in table (1) to calculate the diffusion coefficient charge stimulated by plasma by using equation (1) with values of T_i = 0.1 ev [7] , $n_a = 7.2*10^{19}$ m^{-3} [13] , and σ_i , m_i , and m_e from table (2) , the results are tabulated in table (3) . Another important parameter for diffusion is the overall ion – atom collision frequency v_i – atom that can be calculated from equation (4) , where the gas density n = $7.2*10^{-19}$ m^2 and the values of v , σ_e , and σ_i are taken from table (2) , the values of v_i – atom are summarized in table (4) .

So the other variable in diffusion of charge transport is the collisonal mean free path can be evaluated by using equation (3) and σ_i from table (2) , these calculated values are shown in table (5) .

The diffusion coefficient of am bipolar that caused by the direct ion motion modify the am bipolar flow can be calculated by equation (5) with used value of c_s from table (1) and σ_e , σ_i , T_i , and T_e from table (2) . results are summarized in table (6) also , the cross–field diffusion coefficient D_ρ that describe the electron motion perpendicular to the magnetic field can calculated by used equation (6) after estimated the value of electron gyro radius we estimate the transport properties of the magnetized electrons by used equation (7) and (8) the plasma frequency w can be estimated by using equation (8) , the results are show in table (7) .

The gyro radius of electron ρ can be evaluated when inserting values of w in equation (7) with values of V_i from table (4) the results are summarized in table (8) . finally by using the results of ρ from table (7) with eq (6) , we can calculate the cross field diffusion coefficient the results are listed in table (9) .

All results the ion sound speed C_s , diffusion coefficient D , ion-atom collisions frequency , υ , collision and mean frequency path λ , ambipolar diffusion coefficient D_ρ , ions angular gyro frequency W , and ions gyro radius ρ_i are calculated using amatlab program .

Discussion

For all the results reported here we consider the dimensions of the plasmas are small to justify a transport that relies on thermal equilibration of the electrons.

For the discharge considered here the ion temperature is expected to be reasonably close to the temperature of the neutrals roughly 0.1ev .

The resulting values of the ion sound speed c_s was unusually high for nitrogen and argon comparing with low for hydrogen this indicate of c_s proportional with $1/m_i$.

Table (3) shows the overall diffusion coefficient are large for Nitrogen comparing with Argon and Hydrogen for all the same spectrum temperature value for (1to2.4) ev . This indicates that the diffusion coefficient is depending on the value of c_s sound speed of ion and the scattering cross section for ions that is very view in tables (1) and (2) respectively .

It turned out that the diffusion path way strongly depends on the cross section σ_i . Whereas the diffusion is favored in Nitrogen compare with other elements , thats mean when σ_i small then mean path λ is Large and diffusion coefficient is Large and vice versa .

For electron temperature around (1 to 2.4) ev the ratio of T_i / T_e in equation (1) can be ignored [7] and the directed ion motion modify the am bipolar flow caused the am bipolar diffusion coefficient equation (5) the result of am bipolar diffusion coefficient indicates the diffusion in Nitrogen is more active comparing with Argon and Hydrogen these depending on value of c_s , σ_i and T_e .

Table (9) shows that the cross– field diffusion coefficient D_ρ that described the magnetic field can inhibit electron motion perpendicular to the magnetic field lines . The transport of electrons across magnetic field lines is affected by the magnetic field strength when cross – field diffusion of electron gyro – orbits becomes smaller than the am bipolar diffusion .

Conclusions

In this work , the change transport in magnetized plasma source operation are studies in which the ions motion is controlled by the am bipolar electric field and ion – atom collisions . The sound speed of ion are calculated and found large values for nitrogen and mid large for argon and small for Hydrogen . the most large sound speed leads to height value of diffusion coefficient . in summary , the diffusion coefficients are calculated using equations (1) , (5) and (6)

Showing large value for nitrogen compared with argon and hydrogen depending or co and speed of ion and scattering cross section for ions

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Table (1):The ion sound speed values for Hydrogen , Argon , and Nitrogen

T_e(ev)	c_s(m/s)		
	H_2	A_r	N_2
1	309.34	2447.96	8000
1.1	3244.44	2567.44	8390.47
1.2	338.80	2681.60	8363.56
1.3	352.70	2791.10	9121.40
1.4	366.02	2896.46	9465.72
1.5	378.86	2998.12	9797.95
1.6	391.29	3096.45	10119.28
1.7	403.33	3191.74	10430.72
1.8	415.020	3284.28	10733.12
1.9	426.40	3374.28	11027.23
2	437.47	3461.93	11313.70
2.1	448.28	3547.43	11593.10
2.2	458.83	3630.91	1186.91
2.3	469.14	3712.51	12123.60
2.4	479.23	3792.36	12393.54

Table (2): Velocity of Nitrogen , Argon , and Hydrogen ions and electron

ion	m_i(Kg)	σ_i(m^2)[14]	T_i(eV)[7]	V_i*10^3m/sec
N_2	2.5*10^{-26} kg	2.5*10-17 m^2	0.1 ev	3.577708 m/s
A_r	2.6*10^{-26} kg	3.4*10-17 m^2	0.1 ev	1.094761103 m/s
H_2	1.672*10^{-27} kg	3.9*10-17 m^2	0.1 ev	4.374786393 m/s
Electron	9.1*10^{-31} kg	5*10-19 m^2[7]	1 – 2.4 ev	

Table (3):The ambipolar diffusion coefficient for Nitrogen , Argon , and Hydrogen ions

T_e(ev)	Diffusion coefficient $D(m^2eV/Kg)^{1/2}$		
	H_2	A_r	N_2
1	0.215491275	1.95580081	8.688021893
1.1	0.229542527	2.083315415	9.254354662
1.2	0.24327549	2.208376575	9.809789195
1.3	0.256843827	2.33110882	10.35484973
1.4	0.270142231	2.451753318	10.890642
1.5	0.283219488	2.570477453	11.41790119
1.6	0.296109499	2.687429174	11.9372269
1.7	0.309242861	2.802691618	12.44915585
1.8	0.321338248	2.916426174	12.95422078
1.9	0.333714949	3.028698493	13.45278679
2	0.345936101	3.13965136	13.94553699
2.1	0.358012275	3.249205352	14.4320167
2.2	0.369960597	3.357631219	14.91349599
2.3	0.381775697	3.4648666566	15.38971383
2.4	0.393478486	3.571073853	15.86132399

Table (4): Ion - atom collision frequency for Nitrogen , Argon , and Hydrogen ions

ion	σ_{ion} (m^2)	M_{ion}(kg)	V_{Ar}(m/sec)	υ_{ion}(1/sec)
N2	$2.5*10^{-17}$	$2.5*10^{-26}$	3577.708764	656873.291
Ar	$3.4*10^{-17}$	$2.67*10^{-26}$	1094.761103	2719386.58
H2	$3.9*10^{-17}$	$1.6726*10^{-27}$	4374.786393	12441892.5

Table (5):The collisional mean free path λ and cross section σ_{ion} for Nitrogen ,Argon , and Hydrogen ions

ion	σ_{ion} (m^2)	λ_{ion}(m)
N_2	$2.5*10^{-17}$	$5.555555*10^{-4}$
A_r	$3.4*10^{-17}$	$4.08496732*10^{-4}$
H_2	$3.9*10^{-17}$	$3.561253561*10^{-4}$

Table (6):The ambipolar diffusion coefficient approximation for Nitrogen , Argon , and Hydrogen ions

T_e(ev)	D:ambipolar diffusion coefficient (m^2/sec)		
	H_2	A_r	N_2
1	0.348377135	0.399609066	0.54346833
1.1	0.383208883	0.439563131	0.597805858
1.2	0.417969552	0.479435662	0.652032501
1.3	0.452876917	0.519476464	0.706487991
1.4	0.487723575	0.559447631	0.755197372
1.5	0.522551113	0.599396865	0.815179737
1.6	0.557393162	0.639362745	0.869533333
1.7	0.59222809	0.679320456	0.92387582
1.8	0.62706468	0.719280075	0.978220902
1.9	0.661908994	0.759246235	1.03257488
2	0.696753844	0.799189444	1.086935997
2.1	0.73158014	0.839165455	1.141265019
2.2	0.766420863	0.879130185	1.195617052
2.3	0.801252279	0.919083497	1.249953556
2.4	0.836105966	0.959062751	1.304325342

Table (7):The ions angular gyro frequency w(sec)$^{-1}$ for Nitrogen , Argon , and Hydrogen ions

ions	Magnetic field strength B[15]						
	3*10^{4} Gaus	3.4*10^{4} Gaus	3.8*10^{4} Gaus	4.2*10^{4} Gaus	4.6*10^{4} Gaus	5*10^{4} Gaus	5.4*10^{4} Gaus
A_r	1.797753*10^{11}	2.03745*10^{11}	2.277153*10^{11}	2.5168539*10^{11}	2.75655*10^{11}	2.99625*10^{11}	3.23595*10^{11}
H_2	2.87425*10^{9}	3.257465*10^{9}	3.640718*10^{9}	4.02395209*10^{9}	4.4071856*10^{9}	4.790419*10^{9}	5.173652692*10^{9}
N_2	1.92*10^{12}	2.176*10^{12}	2.432*10^{12}	2.688*10^{12}	2.944*10^{12}	3.2*10^{12}	3.456*10^{12}

Table (8):The ions gyro radius ρ for Nitrogen , Argon , and Hydrogen ions

ions	3*10^{4} Gaus	3.4*10^{4} Gaus	3.8*10^{4} Gaus	4.2*10^{4} Gaus	4.6*10^{4} Gaus	5*10^{4} Gaus	5.4*10^{4} Gaus
A_r	0.151265878	0.133469892	0.11942043	0.108047056	0.098651659	0.090759528	0.084036599
H_2	43.28741766	38.19478028	34.1742771	30.91958404	2.823092456	25.97245059	24.04856536
N_2	0.03421184	0.030186917	0.027009347	0.0244347028	0.022312069	0.020527104	0.019006577

Table (9):The cross field diffusion coefficient D_ρ for Nitrogen , Argon , and Hydrogen ions

	(1/sec)	(1/sec)	(1/sec)	(1/sec)	(1/sec)	(1/sec)	(1/sec)
A_r	38617.0166	30065.15117	24068.77766	19702.55959	16425.00687	13902.12634	11918.83231
H_2	3162424243	2462094998	1971040041	1613481757	1345076474	1138472727	976056864.7
N_2	1975.375388	1537.921949	1231.189612	1007.844538	840.1900102	711.1351395	609.6837117

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انتقال الشحنة في البلازما الممغنطة

هادي جبار مجبل العجيلي ، دريد هاني يونس ، ايناس احمد جواد ، محسن عنيد حسوني
قسم الفيزياء ، كلية التربية – ابن الهيثم ، جامعة بغداد

استلم البحث في :27اذار 2011،قبل البحث في: 7 كانون الاول 2011

الخلاصة

مصدر البلازما يحدد حركة الشحنات في التوزيع غير المتوازن لطاقة الشحنة ويحد من انتقال الالكترونات عبر المجال الممغنط . حركة الالكترونات والشحنات مسيطر عليها بالمجال الكهربائي للتمدد الثنائي ايون – الكترون وتصادمات الشحنة . اعتمد مصدر الكثافة الواجب للالكترونات والايونات الحرارة اللازمة لحساب معامل الانتشار . معامل الانتشار الناشىء من تمدد الكترون ايون، ومعامل الانتشار للشحنة المنتقلة، ومعامل الانتشار التقريبي لتمدد ايونات الالكترون حسبت من خلال مجال البلازما المنتظم . اظهرت النتائج الحقيقية كيفية انحصار عمليات الانتشار من خلال خصائص البلازما .

الكلمات المفتاحية :– انتقال الشحنة ، البلازما الممغنطة ، معامل الانتشار