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Influence of Axial Magnetic Field on the Transport Coefficients of Nitrogen Plasma at Moderate Pressures

S.K. AL- Hakary M. A. Saffo F.M.Al- Badrani

Dep. Of Physics, College of Education
University of Mosul, IRAQ

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الخلاصة:

يتضمن البحث حساب معاملات الانتقال للإلكترون(سرعة الانجراف، والحركية ، والكثافة الإلكترونية) في العمود الموجب لبلازما النتروجين تحت تأثير المجال المغناطيسي المحوري شدته (0-6.5Gauss) وتحت ضغط الغاز المحصور من(0.2 - 5torr) ولمختلف تيارات التفريغ الكهربائي. أظهرت النتائج الى زيادة كلاً من الكثافة والحركية للإلكترون مع زيادة المجال المغناطيسي المحوري وعلى العكس من ذلك نقصان سرعة انجراف الإلكترون مع زيادة المجال المغناطيسي بسبب الاحتواء المغناطيسي للبلازما.وان هذه النتائج على اتفاق جيد مع نتائج البحوث المنشورة السابقة[12], Ferreira and Ricard.

Abstract:-

In the present paper, the transport coefficients (drift velocity, mobility, and density of electron) in a positive column with an axial magnetic field of (0-6.5G) are calculated for Nitrogen plasma at different gas pressures between (0.2-5torr) with different electric discharge currents. The results show that both density and mobility of the electron increases with the increasing an axial magnetic field, contrary to that, drift velocity of electrons due to that increases of an axial magnetic field. This is a result of magnetic field confinement. This is due to the magnetic field confinement. These results show a good agreement with the previous studies (Ferreira and Ricard [12].

1- Introduction:

In the presence of magnetic field, the diffusion coefficient perpendicular to the magnetic field is appreciably altered Kouun, [1] .In this case the main motion of particles is a long the magnetic field. Another influence of the magnetic field on the motion of charged particles is the occurrence of the drift motions associated with no uniformity of the field. The theoretical interpretation of these phenomena were provided by Tonker and Allis [3] , who analyzed the drift velocity of the charged particles in the presence of crossed electric and magnetic fields Tonkr [3] and Kaned [4] , have studied the axial electric of a positive column in a transverse magnetic field theoretically by considering the wall effect, but there have been no studies of a theory of electron temperature which includes the wall effect in the positive in transverse magnetic field. The investigation of the force acting on the particles is the study of the cloud in the presence of a magnetic field Uchida,G.,and etal. [5].Since the cloud is located in a region with high electric field should causes in an a zimthal (E x B) ion drift and therefore a rotation of the cloud in the horizontal plane. Konopka,[6], has studied the effect of a vertical magnetic field on the particles cloud in the sheath of an RF He plasma at various discharge condition. The results show that the magnetic field causes a rotation of the cloud and the angular velocity strongly depends on the plasma conditions. On the other hand, Hassouba, [7] has studied the effect of the magnetic field on the plasma parameters in the cathode fall region of the D.C glow discharge, in the presence of a magnetic field. The measured electron temperatures are smaller than without magnetic field, while plasma density increased by a factor two than that without magnetic field. This is due to confinement, because the magnetic field drift velocity plays an important role to make the radial distribution of T_e always slightly changed. Recently Krinberg,[8], has observed, when an axial magnetic field is applied to the vacuum arc the radial expansion of plasma from cathode spots transforms into a plasma flow along the magnetic field. Furthermore, the electron-ion collision of frequency is smaller than the Lamer frequency.

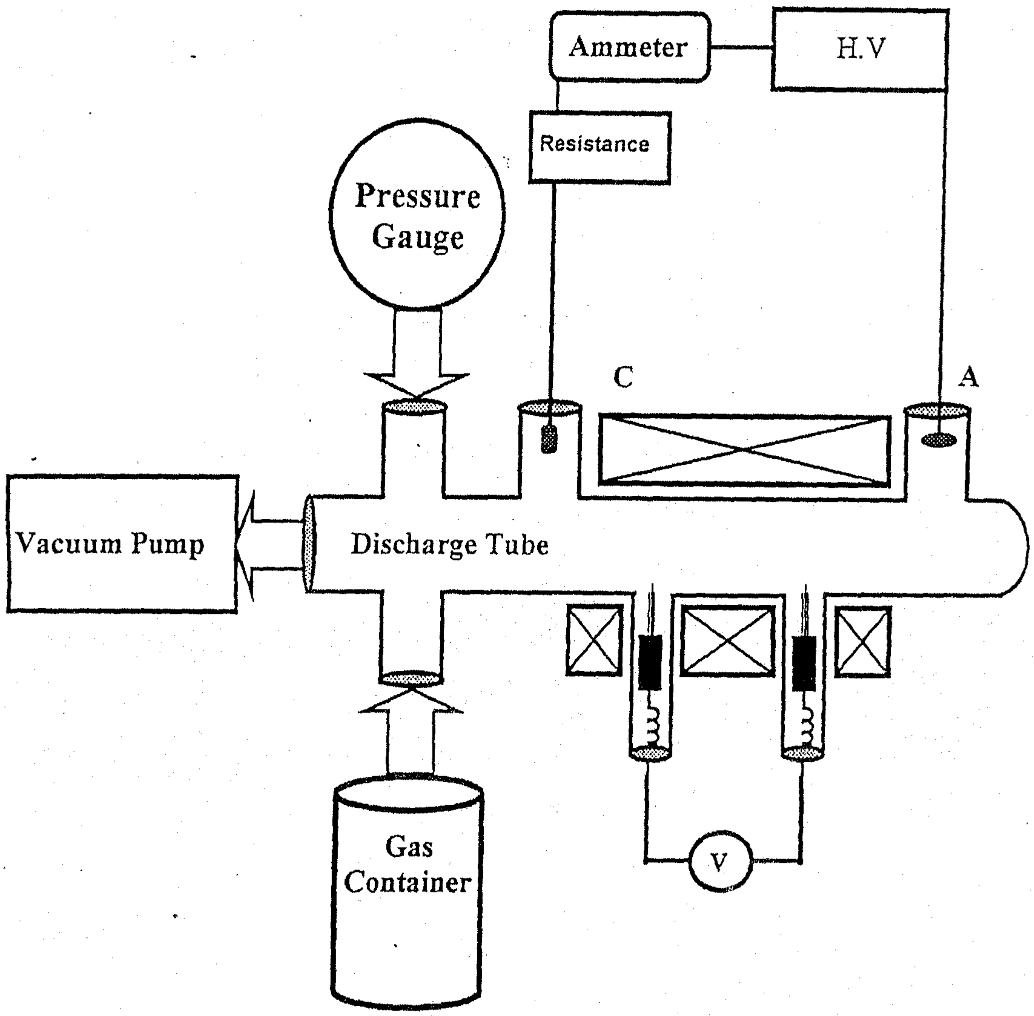
In the present work, the experimental results for the transport coefficients (drift velocity and mobility of electron) as well as the electron density of a positive column are shown for Nitrogen plasma in an axial magnetic field. Furthermore, the experimental results are compared with the previous paper and there is reasonable agreement between them.

2- Experimental procedure:-

The experimental system employed for present study is shown in figure (1).The discharge tube is made of Pyrex glass of radius 1.4cm, and the distance between the electrodes is about 25cm.Ahollow cylindrical cathode which is constructed from Nickel material of 0.78cm. In length such shape of cathode may be served to avoid the formation saturation. But the anode is taken as a circular disc of aluminum. Both electrodes are fixed in a vertical position with respect to the two probes direction. Floating double probes measurements are made nearly at the mid point between the electrodes to measure the difference of floating potential between them as a function of discharge current. Both probes are constructed from tungsten wire 0.5mm in diameter with 2mm length which immersed in to the plasma , the probes have the same shape of identical cylindrical which covered by two glass sleeves. An external adjustment technique has been used to change the probe radial position by means of magnetic effect on a cylindrical iron placed in the probes parts. The discharge tube was evacuated from air by the rotary pump and the gas pressure was measured by means of ionization gauge. The ballast resistance (10 k Ω) limited discharge current and kept the (H .V) unit within it's current capacity. The floating potential difference between probes is measured by using the digital avometer of impedance (10M Ω). Commercial nitrogen gas at purity 98% has been used to produce plasma.

3- Results and Discussion: -

The measurements of plasma transport coefficients (electron density, drift velocity, and mobility) of electron have been performed for representative experimental conditions such as used by Futhe [9] in a hallow cathode D.C glow discharge in nitrogen gas. The discharge conditions were measured in a gas at pressure ranged from 0:2 to 5 torr. And with an external magnetic field of about 6.5 Gauss. The measured (I-V) characteristics are used as abasis to determine the transport coefficients for different discharge current and the ratio of axial electric field to the density of neutral particles of gas (E/N).



Fig(1): Electric Glow Discharge System

3-1 Drift velocity of electrons:-

The diffusion, or drift velocity (V_d) of charged particles in an electric field is proportional to the field strength (E), and the proportionality factor is called the mobility (μ), of the particles Chen, [2].

$$V_d = \mu\ E \ldots\ldots\ldots\ldots\ (1)$$

In nitrogen gas, the relations used for electron drift velocity were those of Bayle, P. and etal. [3], as follows:-

$$V_d\ (cm/s) = 3x10^6 + 8.04x10^6\ E/N \ldots\ldots(2)$$

Where E/N in Townsend (Td) and 1 Td = 10^{-21} V m^2 .

The drift velocity versus of the ratio E/N is shown in Figure (2) which is in a good agreement with equation (2) Ferreira and Ricard [12]. But the drift velocity both pressure and discharge current on the drift velocity of electron as shown in Figure (3) .it is appear from the figure that of V_d decreases with the increases. This is due to the collision frequency (ν_{ea}) of electron with the atoms Uchida,[5] .However, the increasing discharge currents, leading to increase the drift velocity, because the input power to the discharge tube to be will increases and will gain more energy to drift Konopka,[6].

3-2 Electron mobility:-

The concept of mobility is used in plasma physics, is to describe the drift velocity of charged particles under the impact of an electric field Hassouba,[7].The mobility of charged particles is defined as the drift velocity per electric field. The mobility is related with the electro- neutral collision frequency (ν_{ea}) as follows Krinberg,[8] :-

$$\mu = e / (m_e \nu_{ea}) \ldots\ldots\ldots\ldots\ldots\ (3)$$

Figure (4) shows The electron mobility as a function of the axial electric field for different gas pressures (0.2,0.3,0.4,0.5, 5torr)it is from this figure that the mobility decreases with increases the axial electric field. The electron mobility dependence on gas pressure for different discharge currents is shown in Figure (5), this is attributed to increasing the collision frequency of the electron with the neutral plasma particles. As well as increasing the discharge current cause the increasing the input power to the system, this in turn to increases the kinetic energy of the electron, consequently the probability of collision of electron with the other particles will increases according to that.

3-3 Electron density:-

The plasma density is an important parameter in plasma processing because the efficiency of these processes occurring in the plasma and their reaction rate are generally dependent on the density of the charged particles Uchida,[5].
Conductivity or resistivity can easily be used to find the electron density of ionized gas, using the following equation:-

$$\sigma = n e \mu e \qquad (8)$$

Where σ is the electrical conductivity (equal to J/E).The nearly decreasing exponential of the electron density versus gas pressure is shown in figure (6).Because at low pressure the mean free path of electron will be more than it's value at high pressure, therefore, the electron will gain more energy to ionize the gas atoms and finally the increasing the electron density. Furthermore the effect of the discharge current on the electron density is increase due to the input power.

3-4 Plasma Transport Coefficients under Magnetic Field Effect: -

When a magnetic field acts upon a glow discharge the arc plasma, various changes happen, such as, increase of equivalent pressure, a change of radial ion, electron density and a marked change in the voltage current characteristics take place Gerhard, [10]. In the present work, the results show that the axial magnetic field has a noticeable effect on the transport coefficient. In the other word, increasing both density and mobility of electron, this is due to, the magnetic field confine the plasma charged particles and reduce the diffusion of the charged particles toward the wall, leading to the increase the equivalent gas pressure Gerhard,[10].
Consequently both the density and mobility increases with the axial magnetic field as shown in figures (6,7,10,&11). Contrary to this effect the electron drift velocity decreases due to the increasing in the magnetic field in an exponential form as shown in figure (8&9).

4- Conclusions:-

In abnormal glow discharge under d.c excitation at different pressure with various values of the axial magnetic field ranged (0-6.5G) some remarkable results have been observed;

1- For different gas pressures the drift velocity of electron vary linearly with the ratio E/N which satisfying the Bayle and Cornboise relations. Contrary to this behavior the electron mobility vary inversely with the ratio E/N.

2- The variations of the drift velocity, mobility & and electron density with pressure nearly have the same exponential behavior, this is attributed to the increase in collision frequency of the electron with other species.

3- The drift velocity decreases with the increasing the magnetic field. While both the electron mobility and it's density increases with increasing the magnetic field.

4-That the magnetic field changed the equivalent plasma pressure and the collision frequency of the electron with the other particles due to it's confinement.

5- Finally, the effect of the axial magnetic field to confine plasma charged particles is equivalent to the increasing plasma pressure.

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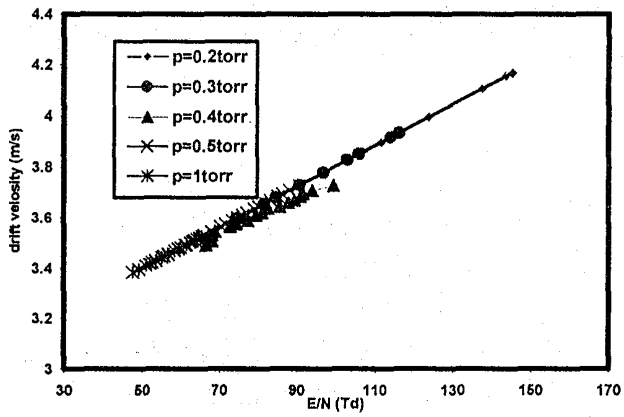
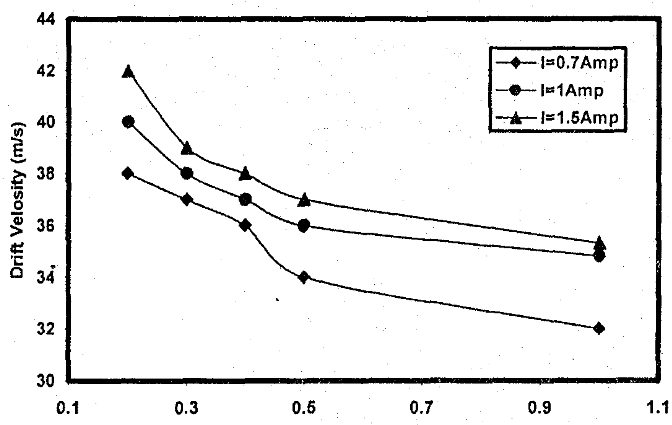
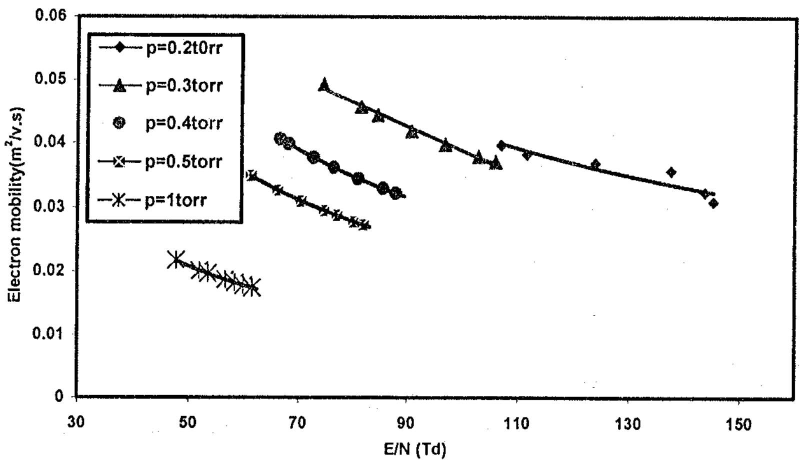


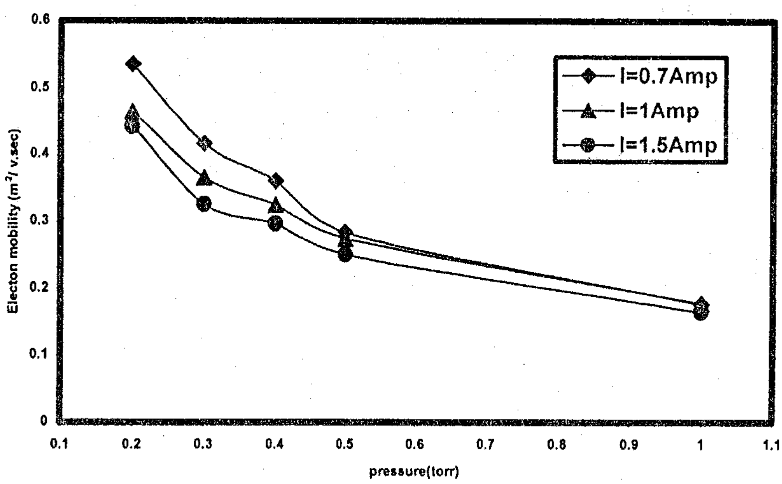
Fig(2): drift velocity as afunction of the ratio of E /N for different values of gas pressures



Fig(3): drift velocity as afunction of gas pressures for different values of discharge currents



Fig(4):The calculated electric mobility as afunction of the axial electrc field for different values of gas pressures



Fig(5): Electon mobility as a function of gas pressures for different values of discharge currents

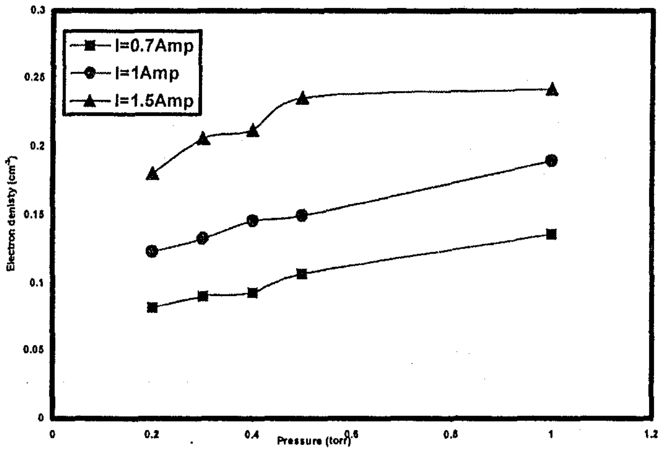
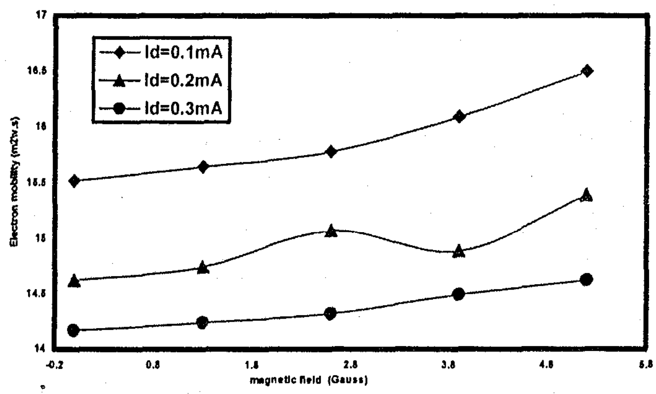
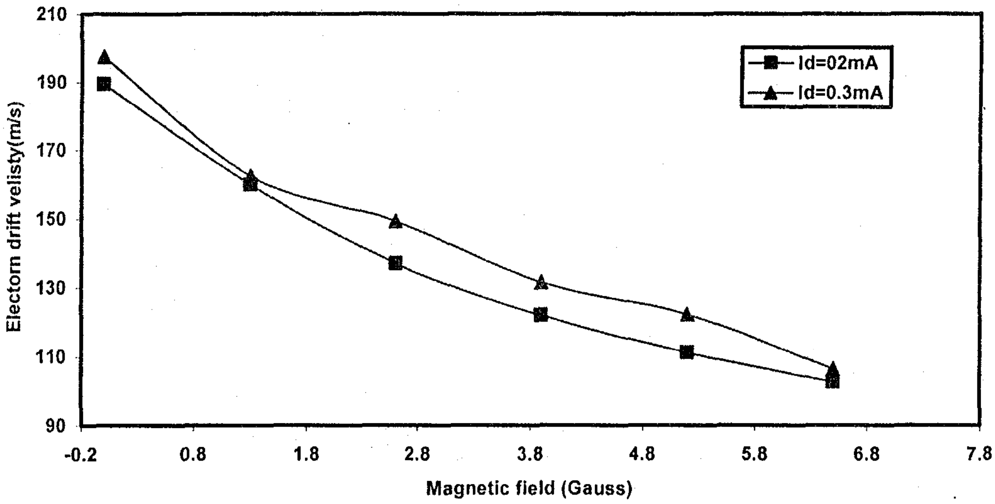


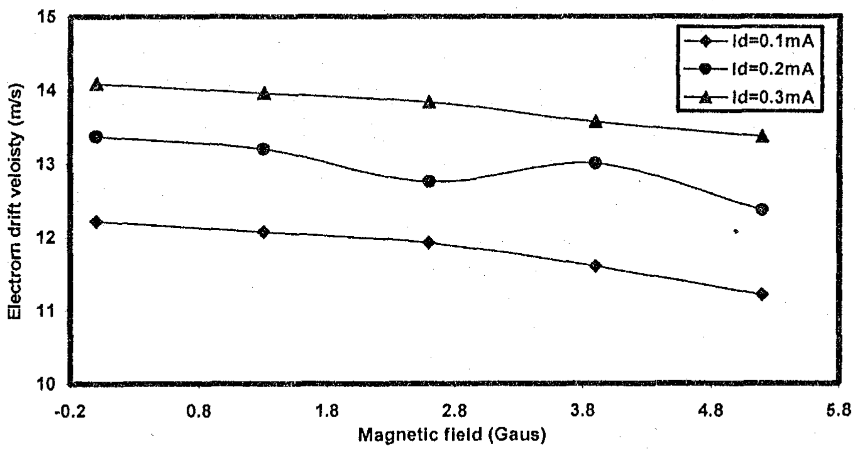
Fig (6): Electron denisty as a function of the gas pressure for different values of discharge currents



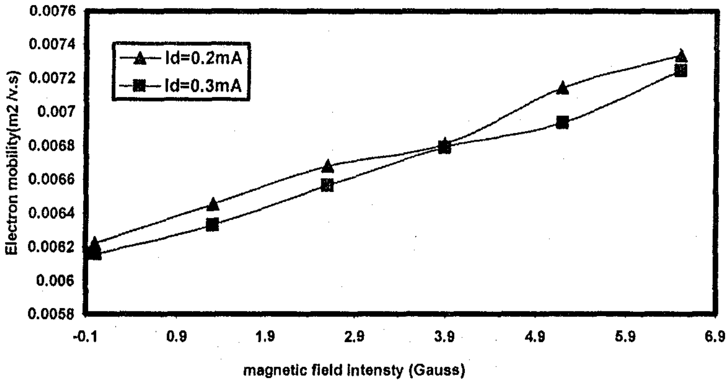
Fiig(7): Electron mobility as a function of the axial magnetic field at different values discharge current at pressure 1torr.



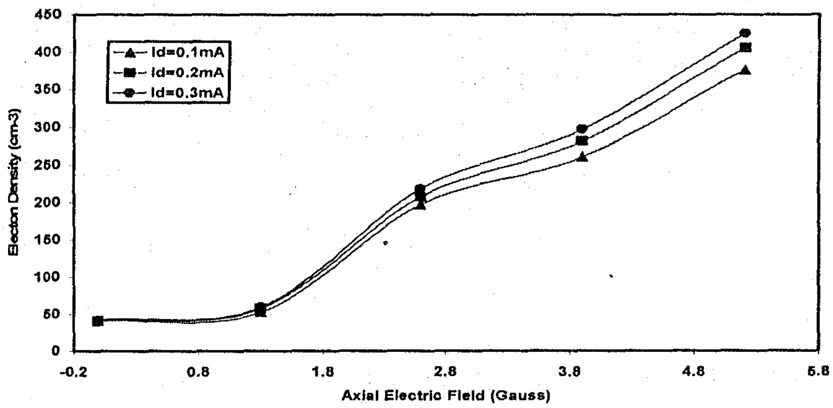
Fig(8): Electorn drift velisty as a function of magnetic field for different values of discharge currents at pressure 5 torr



Fig(9): Electrorn drift veloisty as a function of the axial magnetic field for different values of dischage current at pressure 1 torr



Fig(10): Electron mobility as a function of the axial magnetic field at different values discharge current at(pressure 5torr).



Fig(11):Electron denisty as a function of the axial magnetic field for different values of discharge currents at (pressure 1torr).