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Effect of Magnetic Field on Argon Plasma Properties

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Abstract

This study investigates the influence of an external magnetic field on the fundamental properties of argon plasma, with a specific focus on electronic and ionic densities. Experimental results obtained under varying magnetic field intensities demonstrate a significant impact on plasma behavior. The application of a magnetic field resulted in a notable increase in both electronic and ionic densities, with electronic density rising by approximately 20% and ionic density by 6%, indicating a direct proportional relationship with the strength of the magnetic field. These findings also suggest alterations in the characteristics of the electric field within the plasma environment. The results underscore the magnetic field' S role in modulating plasma parameters and provide insights that may inform the design and optimization of plasma-based systems in both research and industrial contexts.

Keywords: Argon Plasma; Magnetic Field; Electronic Density; Ionic Density; Plasma Diagnostics

Introduction

Plasma is fourth state of substrate, it is ionized gas where cold plasma of ionized weaken gases consist negative charges (electrons, ions) positive charges (ions) as well as neutral particles [1].

It characters with electric properties such as ionization degree, electron temperature, Debye length, plasma potential.

Electric field gradating (E) of plasma and applied magnetic field (B) effect electric charges with Lorentz force:

F=q (E+VXB) … …. (1)

Applied magnetic field (B) constricts neighbor electrons of target if was accident frequency (electron-ion) less than cyclotron frequency of electrons and it changes directions to circular directions about magnetic field lines, then increasing density it in this region from target where it permits with increase ionization ratio of gas atoms, consequently ionic gun of target increasing which produces increase Deposition Velocity [2].

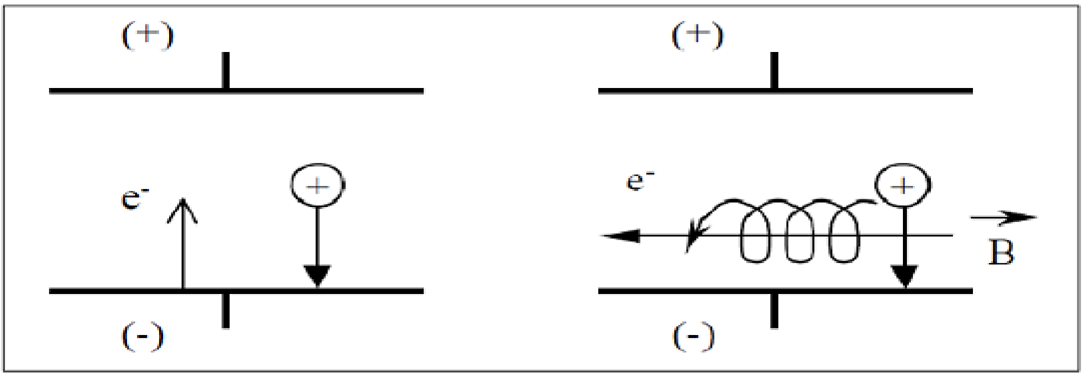


Fig. 1. Effect of magnetic field on electrons direction

Argon gas is rare gas important for spray solid target, it characters with two important properties, it is no active and it has high ionization degree, where it uses in surfaces treatment of plasma and thin films[3].

Theory

Equations in cylindrical coordinates:

In this study, fluid equations in cylindrical coordinates (R,θ,Z),where differential operate $\vec{\nabla}$ in cylindrical coordinates with:

$$\vec{\nabla}\vec{A} = \frac{1}{r}\frac{\partial}{\partial r}(rA_r) + \frac{1}{r}\frac{\partial A_\theta}{\partial \theta} + \frac{\partial A_Z}{\partial Z} \text{.............}(2)$$

$$\vec{\nabla}\varphi = \frac{\partial \varphi}{\partial r}\vec{e}_r + \frac{1}{r}\frac{\partial \varphi}{\partial \theta}\vec{e}_\theta + \frac{\partial \varphi}{\partial z}\vec{e}_z \text{..............}(3)$$

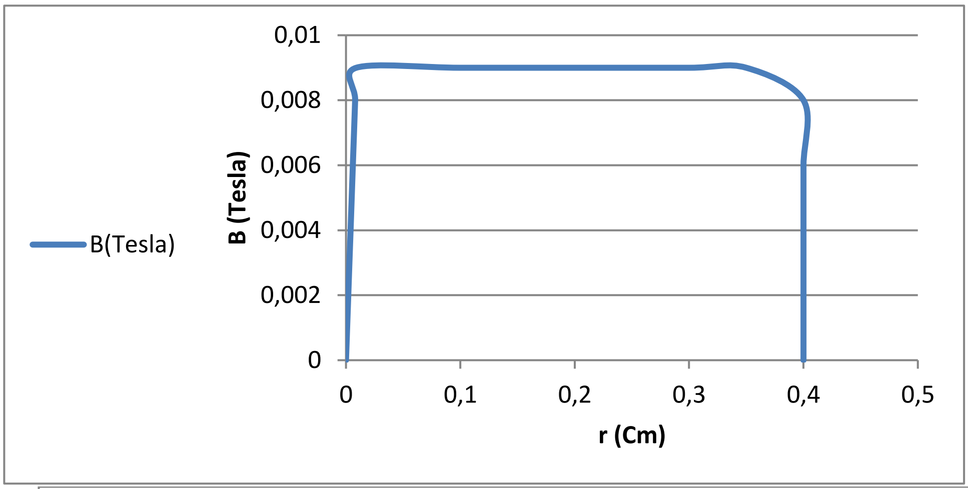
If magnetic field (B) is not zero and $\vec{B} = (B_r,0,0)$ which changes on two axises (r,z) according to following equation [**4**]:

$$B_Z(r,z) = \begin{cases} \frac{B_0(Z)}{r_1^2} r^2 \ldots\ldots\ldots\ldots 0 \le r \le r_1 \\ B_0(z) \ldots\ldots\ldots\ldots\ldots\ldots r_1 \prec r \le r_2 \\ \frac{B_0(Z)}{(r_2-R)^2}(r-R)^2 \ldots\ldots r_2 \prec r \le R \end{cases} \ldots\ldots\ldots\ldots(4)$$

B_0 (z) is magnetic field amplitude where changes according to following linear equation:

$$B_0(z) = \begin{cases} B_0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 0 \le Z \le Z_1 \\ \frac{B_0}{(Z_2-Z_1)} Z - \frac{B_0 Z_1}{(Z_2-Z_1)} \ldots\ldots Z_1 \prec Z \le Z_2 \\ 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Z_2 \prec Z \le H \end{cases} \ldots\ldots\ldots\ldots(5)$$

B_0 is the constant value for magnetic field



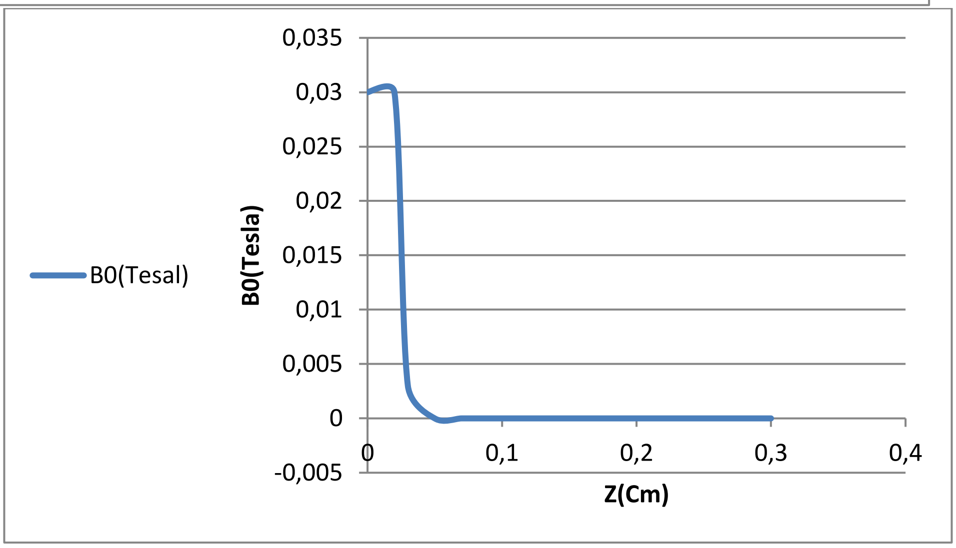


Fig. 2. The change of magnetic field on axises (r & z).

Results and Discussion

1. The effect of magnetic field on electric properties of plasma:

From two equations (4,5), note that the change of magnetic field on axises (r & z) where this change confine on axis Z in very small field with near from landing-strip about (0.6 cm), while the axis (r); the magnetic field appears on complete diameter and it takes the value $B_0(Z)$ in this field about (3.2cm) from it.

On basic this change of magnetic field, electronic density, ionic density, electric field and voltage field will change as following:

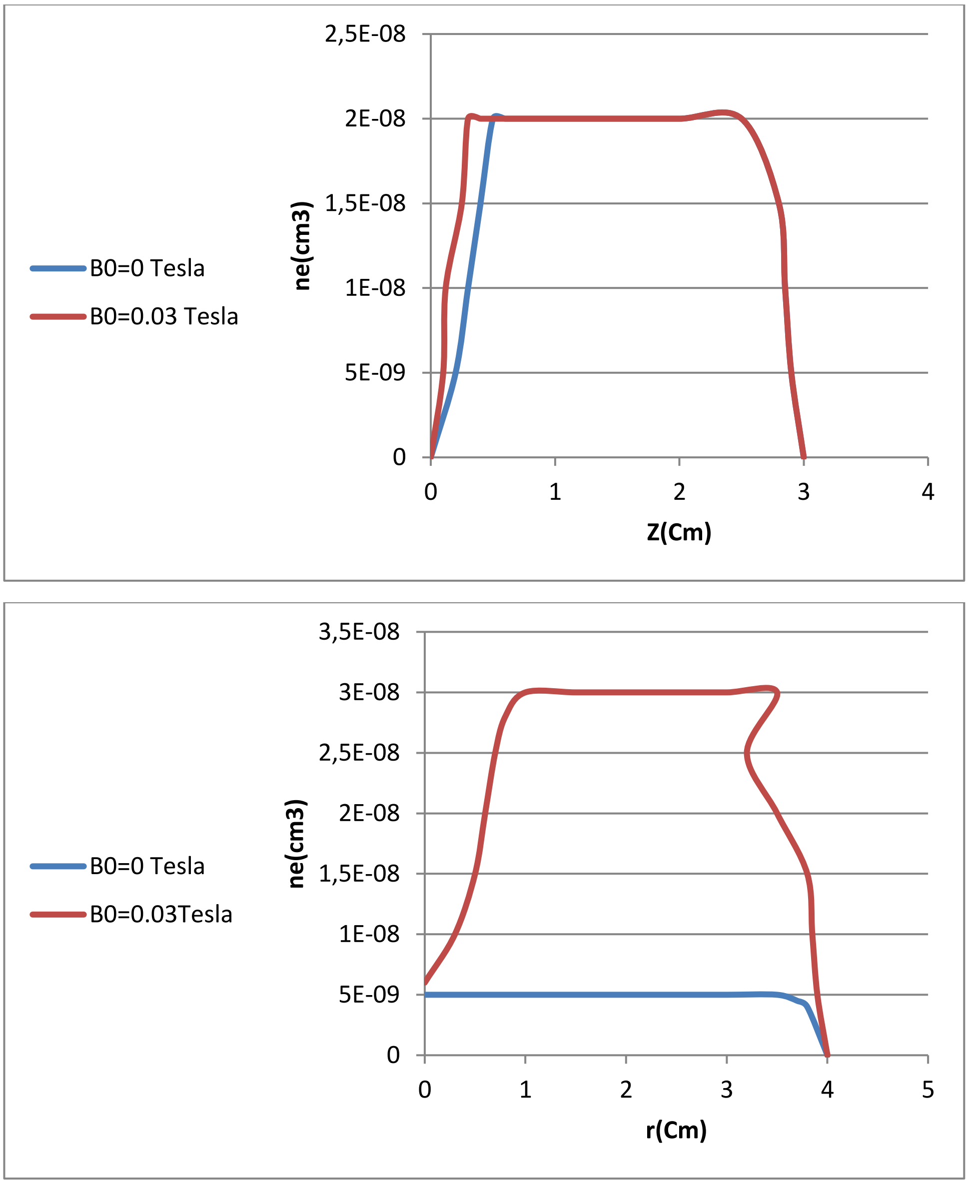
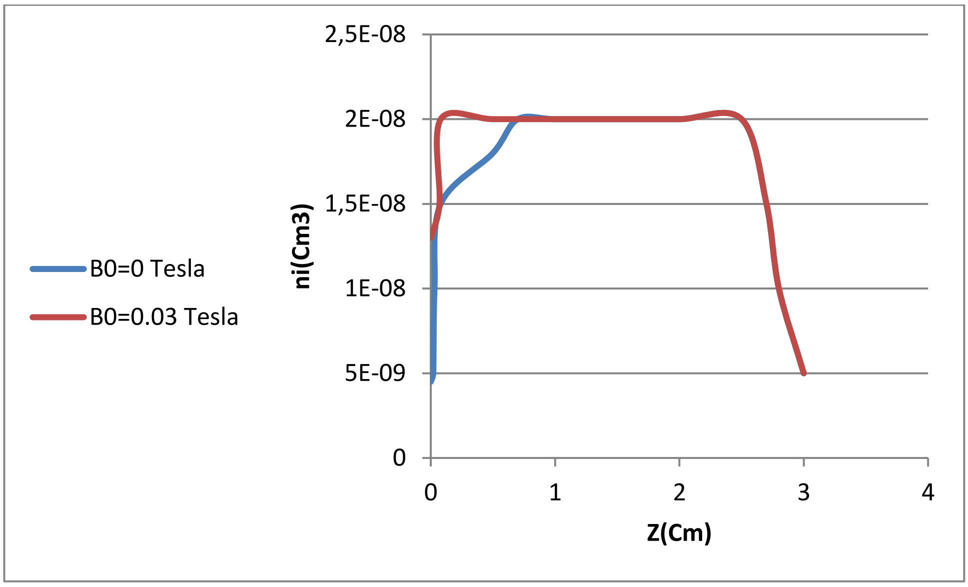


Fig.3. Position change of electronic density with denotation magnetic field.



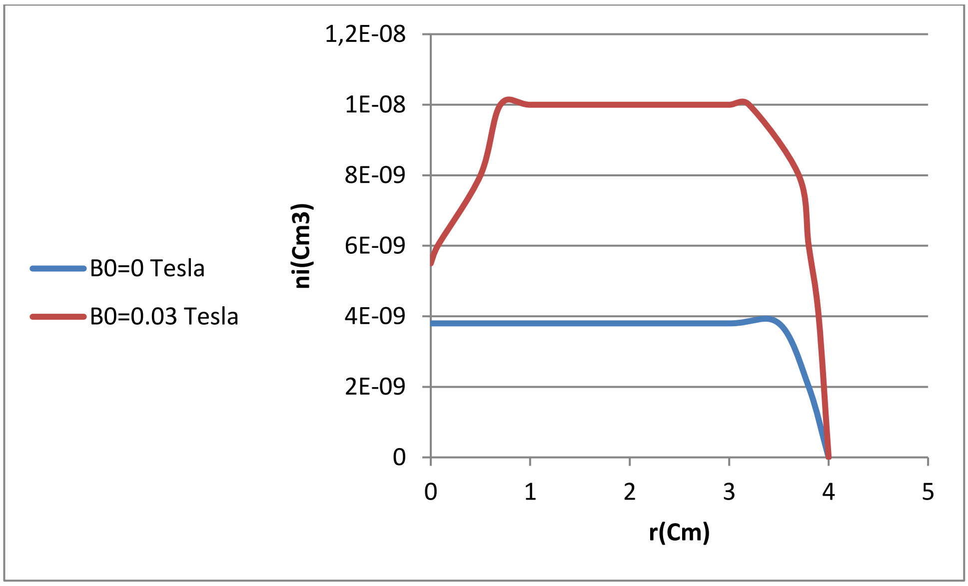


Fig. 4. Position change of ionic density with denotation magnetic field.

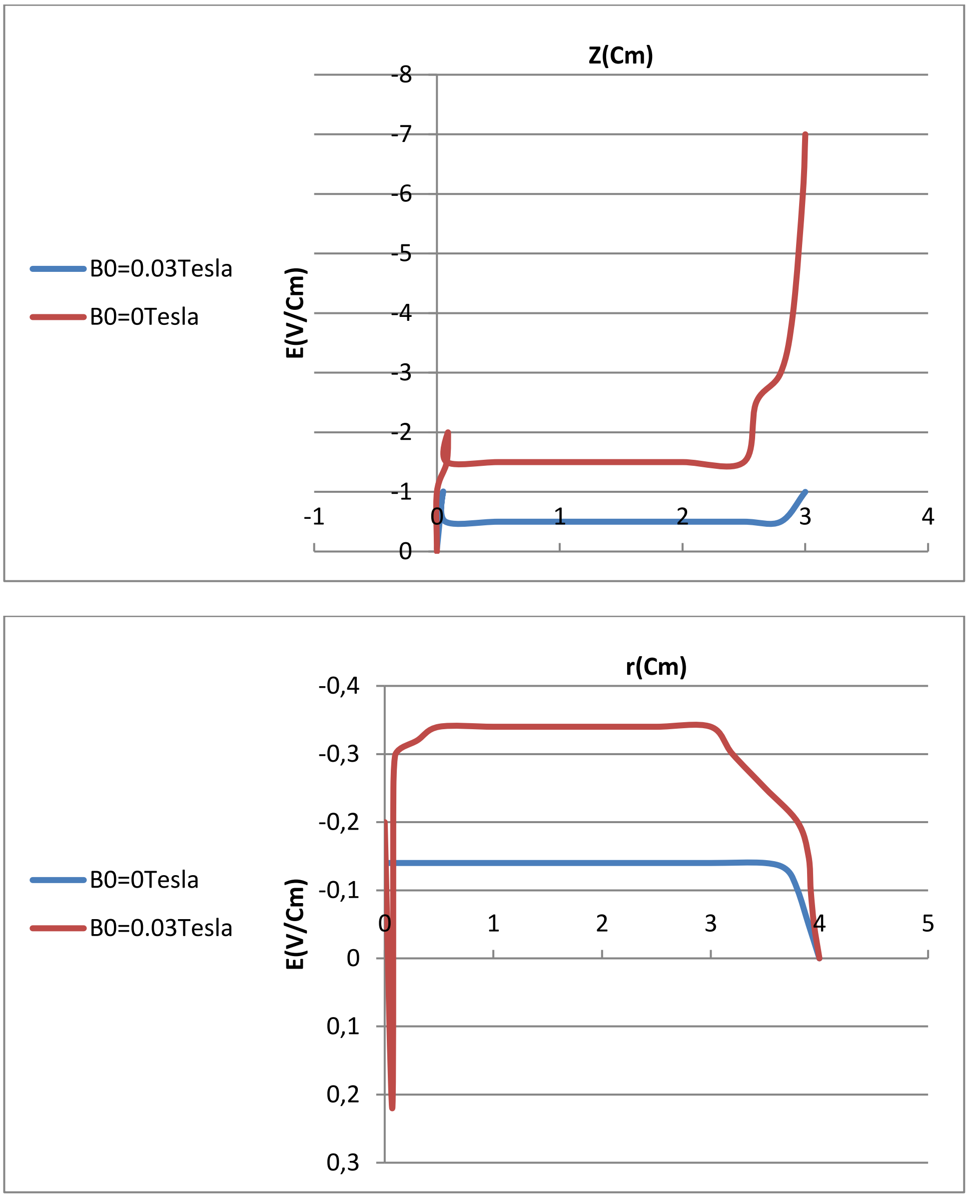


Fig. 5 Position change of electric field with denotation magnetic field.

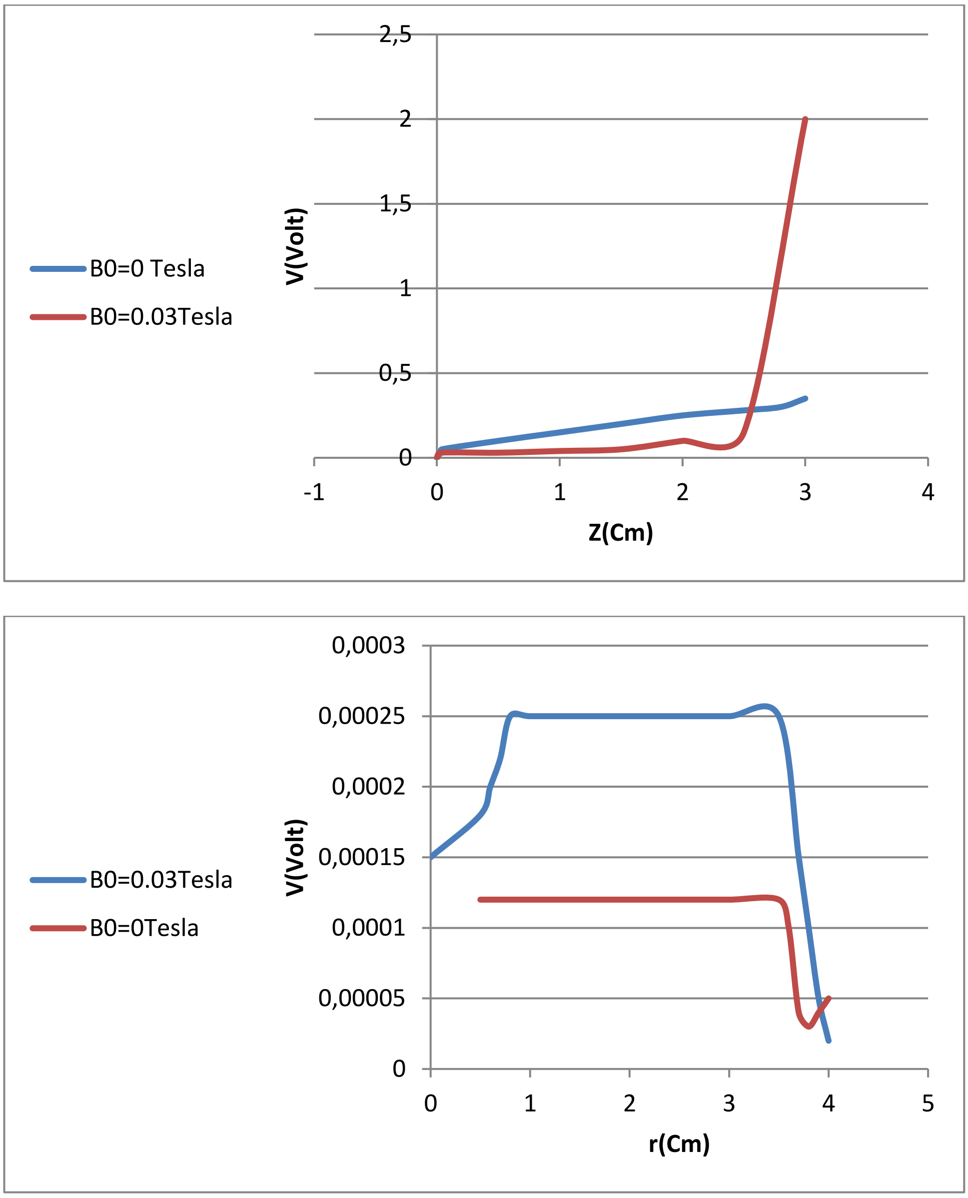


Fig. 6. Position change of voltage field with denotation magnetic field.

Figures (3) to (6) show position change of electronic density, ionic density, electric field and voltage field with denotation magnetic field on two axises r,z consequently

From two figures (3-a) and (4-a), note increasing electronic and ionic density in existing magnetic field initially from anode and along distance (0.057cm),this field according to applied magnetic field between anode and cathode,where increasing percentage (1.33%),then two curves (B=0,B=0.03Tesla) in accepted on departing from anode, until complete identity happen between together. this behavior agree if no magnetic field.

Two figures (3-b) and(4-b) show increasing in ionic and electronic density of axis **r** from through Z point near from anode where

change of electronic density and ionic density on axis r at point Z Very close from cathode, through these two figures appear increasing two densities electronic and ionic on full radius by a large margin, unlike what we' Ve seen on the axis Z, where estimated percentage increase in the electronic density of about 23.6%, while the ionic density were increasing by 6.8%, then curves back at the edge congruence while par value of density (electronic and ionic) in the absence of magnetic field and presences it. This is due to the absence of the magnetic field at this point, and then applied the marginal conditions. Also can be referred to the important note since it whenever we moved away from the cathode (increased waypoint point Z), the less the difference between the maximum value that eliminates this difference, and curves correspond exactly to the point for the electronic density or density ionic, a result of waiting according to the shape of the magnetic field change[5]. This increase in electron density and ion density generated by the increase in value of the electric field by 0.76% on the Z-axis and 2.2 on the r axis to increase the voltage on the axis 1.49%[6].

Explain the influence of the magnetic field on the electrical properties of the plasma by its high impact on Mobility of electrons where he works to change their routes to the circular paths around the lines, thus High density and ability to ionize the gas atoms, which results in high ionic density[7,8].

The table (1) represents the change the percentage increase in the electrical characteristics on the axis r with change B_0.

Table 1: the change the percentage increase in the electrical characteristics on the axis r with change magnetic field B_0

Increase with B_0	$n_e(cm^3)$	$n_i(cm^3)$	E(v/cm)	V(vo.)
0.03~0.01	13	4	3	2.5
0.3~0.03	46	7	1.5	1.8

Conclusions

In plasma argon properties, found that the magnetic field had a clear effect on the electronic density and ionic density, where the percentage of increase was rather large and directly proportional to the increase in the intensity of the applied magnetic field, the percentage was estimated (20%). For the electronic density and (6%) for the ionic density, as was the ratio of the electric field. their characteristics.

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