ON THE DETERMINATION OF THE VALUES $\omega_H\tau$ AND THE EFFECTIVE COLLISION FREQUENCIES OF PLASMA ELECTRONS AND IONS IN A MAGNETIC FIELD

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The values of $\omega_H\tau$ for ions and electrons of a plasma column in a longitudinal magnetic field can be determined with aid of two plane probes (single and double), by measuring the radial and azimuthal diffusion currents with them. The values thus obtained can be used to determine the mean collision frequencies of electrons and ions. Examples of such measurements in argon are presented for various gas pressures. The values thus derived are compared with the calculated values.

A longitudinal homogeneous magnetic field applied to a low pressure cylindrical plasma (positive column) produces in the plasma a transverse drift ("Hall" diffusion) of the electrons and ions in the azimuthal direction, perpendicular both to the direction of the concentration gradient ($\nabla n \parallel \mathbf{r}$), and to the magnetic field ($H \parallel Oz$).[1] The diffusion of the electrons and ions towards the walls in a tube with non-conducting walls is ambipolar, with total velocity $v_r = -D_a \nabla n/n$. To the contrary, the azimuthal drift takes place with velocities $v_{p\varphi} = -\omega_{Hp}\tau_p v_r$ and $v_{e\varphi} = \omega_{He}\tau_e v_r$, which differ from each other in direction and in magnitude. One of the results of this drift is the rotational magnetomechanic effect of the plasma.[2]

This azimuthal diffusion can be used to determine the influence of the magnetic field on the plasma electrons and ions, and also the mean collision frequencies of both ($\nu_e = \tau_e^{-1}$, $\nu_p = \tau_p^{-1}$). For this purpose it is sufficient to measure the densities of the electron and ion currents towards the walls (j_{er} and j_{pr}) and in the azimuthal direction ($j_{e\varphi}$ and $j_{p\varphi}$) in the same place (say at the wall). Since

$$j_{pr} = -j_{er} = e_0 n v_r, \qquad j_{e\varphi} = -e_0 n v_{e\varphi}, \qquad j_{p\varphi} = e_0 n v_{p\varphi},$$

we have

$$j_{p\varphi}/j_{pr} = v_{p\varphi}/v_r = \omega_{Hp}\tau_p, \qquad j_{e\varphi}/j_{er} = v_{e\varphi}/v_r = \omega_{He}\tau_e.$$

We made measurements of this kind in inert gases with the aid of two probes. One probe was flat, and perpendicular to the radius of the tube, and is used to measure j_r. The second was a flat double probe, made of two metallic square plates separated by a thin glass plate, the ends sealed in glass (Fig. 1), and placed parallel to the z, r plane at the same distance from the axis as the first probe. This probe measured the φ-component of the particle current on both sides of the probe. By applying to these probes suitable potentials relative to the comparison electrode, we determined the electronic and ionic currents in the radial and azimuthal directions; from these currents we calculated the mean collision frequencies ν_e and ν_p of the plasma electrons and ions in the magnetic field.* The values of ν_e and ν_p thus obtained were compared with the calculations based on the effective cross sections of the gas molecules relative to the electrons and ions and

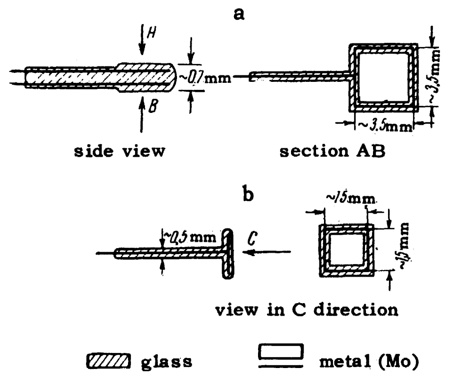

FIG. 1. Diagrams of probes: a) dual b) single.

*At small values of $\omega_H\tau$ (high pressures, weak magnetic fields), an error can creep into the determination of the azimuthal drift current j_ϕ if the probe is not accurately set relative to the (z, r) plane. The relative error in j_ϕ may be of the order of unity if the probe is tilted relative to the radius r by an angle $\alpha \sim \omega_H\tau$. However, in repeated installations of the probe this error becomes random and not systematic, and is thus averaged in the repeated measurements.

p, μ Hg	j, ma/cm²			$\omega_{He}\tau_e$	$\omega_{Hp}\tau_p$	$10^{-6}\nu_p$, sec^{-1}		$10^{-8}\nu_e$, sec^{-1}	
	j_r	$j_{e\varphi}$	$j_{p\varphi}$			measurement	calculation	measurement	calculation
5	0,6	70.2	0.45	117	0.75	0.13	0.15	0.6	~0.1
50	0,61	11.8	0.05	19.5	0,075	1,3	1,5	3.6	~1
500	0,62	3.1	0.006	5	0.0091	11	15	14	~10

on the mean energy of these particles.[3-5] The measurements were made in an argon-filled tube 37 mm in diameter, at H = 400 oe and a discharge current of 0.5 amp. The azimuthal and radial currents were measured with the corresponding probes many times. Example: at a pressure of 50 μ Hg, the values obtained were $I_{e\varphi}$ = 1.2, 1.1, 1.0, 1.3, 1.2, 1.2, 1.1, 1.2, and 1.3 ma, with an average of 1.18 ma. The area of the probe used to measure the azimuthal current was S ≈ 10 mm², so that the average of j_e was 11.8 ma/cm². The average measurement error does not exceed 10 percent.

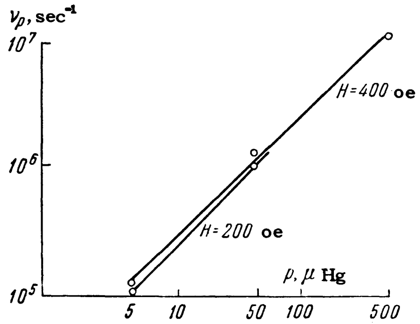

FIG. 2. Dependence of the mean frequency of ion collision on the pressure.

The ion and electron current densities (identified by the subscripts p and e, respectively) obtained in this fashion are listed in the table together with the values of $\omega_H\tau$ calculated for both particles. The results pertain to argon at H = 400 oe, I_z = 500 ma, and tube diameter 37 mm. The dependence of the experimentally obtained values of ν_p on the gas pressure in the plasma is shown in Fig. 2 for two magnetic fields.

These results show that: a) in a field H = 400 oe the influence of the magnetic field on the electron (the value of $\omega_H\tau$) remains appreciable up to p ≤ 10^3 μ Hg; in ions it is small even when p ≈ 5 μ Hg; b) the ion collision frequency ν_p is proportional to the pressure p, and consequently the mean ion velocity does not change noticeably.

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[5] A. von Engel, Ionized Gases, Clarendon Press, Oxford, 1955.

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