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EFFECT OF STATIC ELECTRIC FIELD ON PROPAGATION OF ELECTROMAGNETIC WAVE IN A MAGNETO-PLASMA

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Using a linearized, one-dimensional analysis, the effect of static-electric field E_o on the propagation of an electromagnetic wave along a static magnetic field B_o in a collisional, cold plasma is studied theoretically. The study is made with the aid of the general equations, which specify the dispersion and polarization of plane waves in an ionized medium, pervaded by static electric and magnetic fields. The dispersion relation is obtained from the following laws of physics: (1) Maxwell's law of the electromagnetic fields; (2) the conservation of electrons and positive ions; and (3) Maxwell's law of the transfer of momentum in mixtures of different kinds of particles which are also subject to the fields of force.

Two special cases of interest are considered: case 1 with E_o // B_o and case 2 with $E_o \perp B_o$. For example, it is shown that in case 1, the presence of a longitudinal static electric field may cause a drift of the plasma along the static magnetic field, which in turn causes the change in the attenuation rate of the left- and right-hand circularly polarized waves. At the same time the phase velocities of these circularly polarized component waves are changed so that the plane of polarization rotates as the wave propagates. (This rotation is similar to the phenomenon known as the "Faraday rotation" in optics.) The attenuation rate of the circularly polarized electromagnetic waves, the angle of rotation of plane of polarization, θ (Faraday rotation), and the ellipticity of the polarization may be either increased or decreased with increased static electric field strength, $|E_o|$, depending upon the combination of the system parameters, $\xi = (\omega_p/\omega)^2$, $\eta = (\omega_c/\omega)$, $\zeta = (\nu/\omega)$, and $\delta = (u_o/c)$, as well as the direction of static electric field. Here ω, ω_p, ω_c and ν are the wave angular, electron plasma, electron cyclotron, and electron collision frequency respectively, where $u_o = (- eE_o/m\nu)$, c denotes the drift velocity and the speed of light in a vacuum respectively, and (e/m) is the electronic charge-to-mass ratio. It is observed that when E_o and B_o are anti-parallel ($\delta > 0$), an increase in the static electric field strength $|E_o|$ tends to cause the attenuation rate of the right-hand polarized wave to decrease considerably while it causes the attenuation rate of the left-hand wave to decrease only slightly in the case $\eta > 1$. Whereas for case $\eta < 1$, the increase of $|E_o|$ causes only slight increase in the rate of attenuation for both types of component waves.

On the other hand, when the propagation vector $\underline{k}$ is in the direction of B_o, the Faraday rotation increases with the $|E_o|$ for $\eta < 1$ but decreases with $|E_o|$ for the case $\eta > 1$ in the range $\delta > 0$. It is also shown that under a proper condition, the presence of a static electric field can increase the Faraday rotation significantly. For example, in the case of $\xi = 0.6$, $\eta = 1.4$ and $\delta = 0.06$, the Faraday rotation index $\Delta\mu = (\mu_\ell - \mu_r)$ for the propagation in the direction of B_o takes a value of $- 1.15$ at $\delta = - 0.1$ and of $- 0.7$ at $\delta = 0$. Here μ_ℓ and μ_r are the refractive index of the left- and right-hand polarized wave respectively. This represents an increase of more than 60% in the Faraday rotation as δ is changed from 0 to $- 0.1$, in which E_o and B_o are parallel. On the other hand, for the case of $\xi = 0.2$, $\zeta = 0.16$, $\eta = 0.95$,

$(\Delta\mu)$ takes a value of - 0.04 for $\delta = 0$ and - 0.40 for $\delta = 0.1$. Thus the Faraday rotation may be 10 times greater in the case of the presence of drift, or static electric field, than in the case of nondrifting when $\vec{E}_o$ and $\vec{B}_o$ are antiparallel.

As for case 2, the presence of a transverse static electric field has, in general, very little effect on the propagation of a transverse electromagnetic wave traveling along the static magnetic field. For example, in the range of parameters, ξ, η, ζ and δ considered in case 1, practically no effect of static electric field is observed. However, a slight effect is noted for a special case where $\xi = 1.0$, $\eta = \zeta = 10^{-3}$.

The variation of the Faraday rotation, the attenuation rates of the left- and right-hand polarized wave and the ellipticity of polarization with the system parameters are discussed in detail. A possible application of the theory is also indicated.