§13. Thermoelectric Effect on Magnetic Field Generation

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For a long time, it has been commonly believed that unfavorable pressure gradient can give rise to very strong magnetic fields in unmagnetized nonuniform plasmas [1]. These investigations usually take into account the electron dynamics only, which can be collionless or collisional. Several authors have discussed surface wave-like magnetic electron drift vortex (MEDV) modes [2] in the limit $\omega_{pi} << \omega << \omega_{pe}$ (where ω_{pi}, ω_{pe} are ion and electron plasma oscillation frequencies, respectively). The so-called thermoelectric term $\nabla n_0 \times \nabla T_1$ (where n_0 is the unperturbed density and T_1 is the perturbed electron temperature) is considered to be the main source of magnetic fluctuations in such plasmas.

Recently [3] it has been shown that the magnetic fluctuations can be generated on an ion time scale in the limit $\omega << \omega_{pe}$. The curl of the electron equation of motion in unmagnetized plasmas

$$mn_0\partial_t \mathbf{v}_1 = -en_0\mathbf{E}_1 - \nabla p_1, \qquad (1)$$

does not give

$$\partial_t \nabla \times \mathbf{v}_1 = -\frac{e}{m}\nabla \times \mathbf{E}_1 + \frac{1}{mn_0}\nabla n_0 \times \nabla T_1, \qquad (2)$$

where e is the charge amd m is the mass of an electron. The subscripts naught and one denote the equilibrium and perturbed quantities, respectively. We elaborate this point in detail in the following.

The curl of Eq.(1) gives

$$m(\nabla n_0 \times \partial_t \mathbf{v}_1 + n_0 \nabla \times \partial_t \mathbf{v}_1) = -e(n_0\nabla \times \mathbf{E}_1 + \nabla n_0 \times \mathbf{E}_1), \qquad (3)$$

If one takes the cross product of ∇n_0 with Eq.(1) and then subsitutes the term $\nabla n_0 \times \mathbf{E}_1$ in Eq. (3), one can obtain Eq.(2). Similarly, if one first divides Eq.(1) with n_0 and then takes the curl of the same, it would yield Eq.(2). This is what the previous authors have done to obtain Eq.(2). But, in our opinion, the appearance of the thermoelectric term is due to inappropriate ordering of the terms involved. To elaborate this point, another way to reach Eq.(2) through Eq.(3) has been presented here. By ignoring ion dynamics and displacement current, one drops $(\frac{1}{6.5})$ or $(\frac{1}{7.7})$ compared to 1 in the calculations for H or D-D plasmas. On the other hand, the second term on right-hand side (RHS) of Eq.(3) is $\frac{\kappa_n}{k}$- times smaller than the first (where κ_n^{-1} is the density scale length and k is the wave vector). The local approximation requires $\frac{\kappa_n}{k} << 1$. If $\epsilon \sim \frac{\omega_{pi}}{\omega}$ is the smallness parameter, then $\epsilon \sim \frac{\kappa_n}{k}$ seems natural to be assumed. We notice that on the one hand terms of order ϵ are ignored and on the other hand the thermoelectric term is retained which is also of the same order of magnitude.

This work shows that the thermoelectric term does not seem to be the main source of magnetic field fluctuations linearly. Furthermore the order of magnitude of the magnetic field estimated by including ion motion [3] turns out to be the same as has been observed experimentally.

REFERENCES

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