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Modified Rayleigh equation in E×B plasma having temperature gradient

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Rayleigh–Taylor instability takes place when a lighter fluid supports a heavy fluid and the forces associated with the density gradient and gravity oppose each other. Any perturbation at the interface leads to spikes of the heavier fluid penetrating into the lighter fluid, so that the system can attain a lower potential energy state. In a Hall thruster, the magnetic field (light fluid) is supported by the plasma (heavy fluid) which results in the Rayleigh–Taylor instability [1]. Since the magnetic field lines are curved in shape, the centrifugal force on the plasma acts as an equivalent gravitational force.

In the present work, we have derived a Rayleigh equation in **E×B** plasma which has gradients in the number density and temperature of the ions and the electrons. This is due to the presence of ionization and collisions of the plasma species. For this, we use the linearized form of the continuity and momentum transfer equations for obtaining the expressions for the perturbed density in terms of the perturbed potential. The use of the perturbed densities in the Poisson's equation lead to an equation which has perturbed and unperturbed parts in terms of the electric potential [2]. The part of the equation in terms of the oscillating / perturbed potential resembles usual Rayleigh equation of the fluid dynamics under some conditions and a modified form is attained in the said plasma under the effect of temperature gradient of the ions and the electrons.

The conditions that convert the modified Rayleigh equation into the normal Rayleigh equation are discussed in greater detail. The situations of equal and unequal temperature gradients of the ions and the electrons are discussed for the application of the theoretical model to the Hall thruster devices, where only the electrons are magnetized and the ions are treated as unmagnetized species.

References

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