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MPHYCC-6

M.Sc. Sem II

Plasma Physics

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Paper - MPHYCC-6

Alfven Wave :-

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A transverse magnetohydrodynamic wave travelling in the direction of the magnetic field in a magnetized plasma. The velocity of such waves (The Alfven velocity or speed) is characteristic for a plasma of given properties.

A Alfven wave in a plasma is a low-frequency travelling oscillation of the ions and the magnetic field. The ion mass density provides the inertia and the magnetic field line tension provides the restoring force.

The wave propagates in the direction of the magnetic field, although waves exist at oblique incidence and smoothly change into the magnetosonic wave when the propagation is perpendicular to the magnetic field.

The motion of the ions and the perturbation of magnetic field are in the same direction and transverse to the direction of propagation.

Alfven Velocity :-

The low frequency relative permitivity ε of a magnetized plasma in given by

$$\varepsilon = 1 + \frac{c^2 \mu_0 \rho}{B^2}$$

where B is the magnetic field strength, c is the speed of light, μ_0 is the permeability of the vacuum, and the mass-density is

$$\rho = \sum_s n_s m_s ,$$

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totalled over all charged plasma particles, each specie indexed by s, with ion-number density n_s and individual ionic mass m_s; The sum includes both electrons and ions.

The phase velocity of an electromagnetic wave in such a medium is

$$v = \frac{c}{\sqrt{\epsilon}} = \frac{c}{\sqrt{1+\frac{c^2 \mu_0 \rho}{B^2}}}$$

or $$v = \frac{v_A}{\sqrt{1+\frac{v_A^2}{c^2}}}$$ where $v_A = \frac{B}{\sqrt{\mu_0 \rho}}$

is the Alfven velocity if $v_A << c$, the $v \simeq v_A$. On the other hand, when $v_A \to \infty$ then $v \to c$. i.e. at high field or low density, the velocity of the Alfven wave approaches the speed of light, and the Alfven wave becomes an ordinary electromagnetic wave.

Neglecting the contribution of the electrons to the mass density and assuming that there is a single ion species, we get.

$$v_A = \frac{B}{\sqrt{\mu_0 n_i m_i}} \text{ in SI}$$

$$v_A = \frac{B}{\sqrt{4\pi n_i m_i}} \text{ in Gauss}$$

$$v_A \approx (2.18 \times 10^{+11} \text{ cm s}^{-1})(m_i/m_p)$$

when n_i is the ion number density and m_i is the ion mass.

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In plasma physics, the Alfven time τ_A is an important time scale for wave phenomena. It is related to the Alfven velocity by

$$\tau_A = \frac{a}{v_A}$$

where a denotes the characteristic scale of the system. For example, a 'a' could be the minor radius of the torus in a tokamak.

Relativistic case –

In 1993, Gradalin derived the Alfven wave velocity using relativistic magnetohydrodynamics to be

$$v = \frac{c}{\sqrt{1 + \frac{(e+P)}{2P_m}}}$$

where e is the total energy density of plasma ~~for~~ particles, P is the total plasma pressure, and

$$P_m = \frac{B^2}{2\mu_0}$$

is the magnetic pressure. In the non-relativistic limit $P \ll e \approx \rho c^2$, and we immediatkly recover the expression ~~from~~ ~~the~~

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