MAGNETIC FIELD CREATED BY HYDRODYNAMIC MOTION

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An analytical expression for a magnetic field created by hydrodynamic motion was obtained. The frequency of the Larmor is calculated. Analytical expressions of the magnetic field in longitudinal and transverse waves are different.

Keywords: Larmor frequency, magnetic field, hydrodynamic movement, current flow density, temperature gradient.
PACS: 72.70m, 72.70+m, 73.40 GK; 73.40 Jn, 74.40.Jn, 73.40 Mr, 73.43. Jn

Consider a plasma that does not depend on the coordinates and ∇T. Suppose that the distance after a small one $L = T/|\nabla T|$. Thus, the change in temperature in this range is small.

If $\Delta\rho/\rho = -\nabla T/T$ plasma can be stationary, ρ is plasma density. Create such a weak magnetic field H in this plasma so that the frequency of the Larmor Ω_l of the electrons was less $1/\tau$ than the frequency of the collision. For a sample with an electric field E, ∇n is electron concentration, ∇T temperature gradient and hydrodynamic movement $V(r,t)$, current flow density will be as follows:

$$\vec{J} = \sigma \vec{E}^* + \sigma' \left[\vec{E}' \vec{H}\right] - \alpha \nabla T - \alpha' \left[\nabla \vec{T} \vec{H}\right]$$

$$\vec{E}^* = \vec{E} + \frac{\left[\vec{V}\vec{H}\right]}{c} - \frac{T}{e}\frac{\nabla n}{n} \quad , \qquad e > 0$$

$$rot\vec{H} = \frac{4\pi}{c} j = \frac{4\pi}{c}\sigma\left\{E^* + \frac{\sigma'}{\sigma}\left[\vec{E}^*\vec{H}\right] + \ldots\right\}$$

From formula

$$\vec{E}^* = \frac{c}{4\pi\sigma} rot\vec{H} - \frac{\sigma'}{\sigma}\left[\vec{E}^*\vec{H}\right] + \frac{\alpha}{\sigma}\nabla T + \frac{\alpha}{\sigma}\left[\nabla T\vec{H}\right]$$

or

$$\vec{E}^* = \frac{c}{4\pi\sigma} rot\vec{H} - \frac{\sigma'}{\sigma}\left[\frac{c}{4\pi\sigma} rot\vec{H}, H\right] - \Lambda\frac{\sigma'}{\sigma}\left[\nabla T\vec{H}\right] =$$

$$= \frac{c}{4\pi\sigma} rot\vec{H} - \frac{c\sigma'}{4\pi\sigma^2}\left[rot\vec{H}, H\right] + \Lambda'\left[\nabla T\vec{H}\right] + \Lambda\nabla T$$

Here $\lambda = \dfrac{\alpha}{\sigma}, \quad \lambda' = (\alpha'\sigma - \alpha\sigma')/\sigma^2$

From this one we get

$$\vec{E} = \vec{E}^* - \frac{1}{c}\left[\vec{\upsilon}\vec{H}\right] + \frac{T}{e}\frac{\nabla n}{n} = -\frac{1}{c}\left[\vec{\upsilon}\vec{H}\right] + \Lambda'\left[\nabla T\vec{H}\right] + \frac{c}{4\pi\sigma} rot\vec{H} - \frac{c\sigma'}{4\pi c^2}\left[rot\vec{H}\vec{H}\right] + \frac{T}{e}\frac{\nabla\rho}{\rho} + \lambda\nabla T \tag{1}$$

Write $\dfrac{\partial\vec{H}}{\partial t} = -c\ rotE$ in (1)

$$\frac{\partial H}{\partial t} = rot\left\{\left[\left(\upsilon + c\lambda'\sigma T - \frac{c\sigma'}{4\pi\sigma^2} rotH\right)H\right] + \frac{c}{4\pi\sigma} rotH + \frac{T}{e}\frac{\nabla\rho}{\rho} + \lambda\nabla T\right\}$$

If we exclude secondary members H, we get an expression in the following as

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$$\frac{\partial \vec{H}}{\partial t} - \nu_m \nabla^2 \vec{H} - rot\left[(V - U_T + U_3)H\right] = -c\ rot\vec{E}' \tag{2}$$

Here

$$c\,rotE' = \frac{cT}{e}\tilde{\lambda}\left[\nabla\, ln\, T, \nabla\frac{\rho'}{\rho}\right]$$

$$\tilde{\lambda} = \left[2(\gamma - 1)e\Lambda - \gamma e\rho\frac{\partial \Lambda}{\partial \rho} + 2 - \gamma\right]$$

$$\nu_m = \frac{c^2}{4\pi\sigma} \quad , \quad \rho \sim \rho^{\gamma}$$

$\tilde{\lambda}$ - dimensionless value, ν_m - Magnetic perception at high frequencies.

$$U_3 = \frac{c^2}{4\pi\sigma}\left[\sigma T\frac{\partial}{\partial T}\left(\frac{1}{\sigma}\right)\right]\frac{cT}{eH_0}\nabla \ln T$$

If we consider the longitudinal wave, υ and E the function $\xi = kx - \omega t = k(x - ut)$ is the speed of the wave propagation, in this case the speed of sound coincides with the speed of light. The vector υ is directed towards the axis x direction. ∇T is in the same direction.

Then, when $H = H(\xi, t)$ and at the initial moment (t=0)

$$H(\xi, 0) = 0,$$

Then,

$$\frac{\partial H_\perp}{\partial t} - \nu_m R^2\frac{\partial^2 H_\perp}{\partial \xi^2} - R\frac{\partial}{\partial \xi}\left[(\upsilon - U_T - U + U_3)H_\perp\right] = -c\ rotE'$$

$$H \perp \vec{k}$$

$$\frac{\partial H_x}{\partial t} - \nu_m k^2\frac{\partial^2 H_x}{\partial \xi^2} - k\frac{\partial}{\partial \xi}\left[(\upsilon - U_T - U)H - RU_3\frac{\partial H_y}{\partial \xi}\right] = 0$$

$$H_\perp = H_{\perp\infty}(\xi) + H'_\perp(\xi, t)$$

$$\nu_m k^2\frac{\partial^2 H_{\perp\infty}}{\partial \xi} - R\frac{\partial}{\partial \xi}\left[(\upsilon + U_T - U - U_3)H_{\perp\infty}\right] = cR\frac{\partial E'}{\partial \xi} \tag{3}$$

$$\frac{\partial H'_\perp}{\partial t} - \nu_m k^2\frac{\partial^2 H'_\perp}{\partial \xi^2} - k\frac{\partial}{\partial \xi}\left[(\upsilon + U_T - U)H'_\perp\right] = 0 \tag{4}$$

We integrate the formula (3) by ξ, choose the equivalent of the initial coordinates

$$\nu_m k^2\frac{\partial H_{\perp\infty}}{\partial \zeta} - k\left[(\upsilon + U_T - U - U_3)H_{\perp\infty}\right] = -c\ rotE' \qquad (const = 0)$$

$$\frac{\partial H_{\perp\infty}}{\partial \zeta} - \frac{1}{\nu_m k}\left[(\upsilon + U_T - U - U_3)H_{\perp\infty}\right] = -\frac{c}{k\nu_m}E'$$

$$\frac{d}{d\zeta}H_{\perp\infty}e^{-\int\frac{\upsilon + U_T - U - U_3}{k\nu_m}d\zeta'} = -\frac{c}{k\nu_m}E'e^{-\int\frac{\upsilon + U_T - U - U_3}{k\nu_m}d\zeta'}$$

Here

$$\frac{d}{d\zeta}H_{\perp\infty}e^{-\int\frac{\upsilon+U_T-U-U_3}{k\nu_m}d\zeta'}=-\frac{c}{k\nu_m}E'e^{-\int\frac{\upsilon+U_T-U-U_3}{k\nu_m}d\zeta'}$$

$$H_{\perp\infty}=-\frac{c}{k\nu_m}\exp\left[-\int\frac{U-U_T+U_3-U}{k\nu_m}d\zeta'\right]\times$$
$$\times\int_{\zeta}^{\zeta'}E'(\zeta')\exp\left[\int\frac{U+U_3-U-U_T}{k\nu_m}d\zeta''\right]d\zeta' \qquad (5)$$

If change $H'_\perp(\zeta,t)=e^{\mu t}X(\zeta)$ with $U=U(\zeta)$, then we get

$$\nu_m k^2X''+(kU-\omega_T)X'(\zeta)-\left(k\frac{\partial U}{\partial\zeta}+\mu\right)X=0 \qquad (6)$$
$$\omega_T=\omega-k(U_T-U)$$

We enter a new feature.

$$\mathrm{X}_1=\mathrm{X}\exp\left\{-\frac{1}{2\nu_m R}\int(\upsilon+U_T-U)d\xi\right\}$$
$$\mathrm{X}_1''-\frac{1}{\nu_m R^2}\left[\mu+k\frac{\partial\upsilon}{\partial\rho}+\frac{(\upsilon+U_T-U)^2}{2\nu_m}\right]\mathrm{X}_1=0$$
$$\mathrm{X}(\xi)\sim e^{ix\xi}$$

If $\upsilon(\xi)$ is a periodic function, then (6) - the Mate- Hill equation.

At $\upsilon<<|U-U_T|$, The speed of the oscillation is much less than the speed of sound. $\mathrm{X}(\xi)\sim e^{ix\xi}$,

$$\mu=-ix(\omega-\omega_T)-\nu_m R^2\chi^2 \qquad (7)$$

(4) will be

$$H'(\zeta,t)=\int_{-\infty}^{\infty}C(\chi)\exp[i\chi\xi+\mu t]d\chi$$
$$t=0$$
$$H'(\zeta,t)=\int_{-\infty}^{\infty}C(\chi)e^{i\chi\xi}d\chi=-H_\infty(\xi)$$

From here it can be seen that $C(\chi)H_\infty(\xi)$ is Fourier row.

$$H(\zeta,t)=H_\infty(\zeta)-\frac{1}{2\pi}\int_{-\infty}^{\infty}dx\int_{-\infty}^{\infty}d\zeta' H_\infty(\zeta')\exp\left\{ix\left[\zeta-\zeta'+(\omega-\omega_T)t-\nu_m k^2x^2t\right]\right\}=$$
$$=H_\infty(\zeta)-\left(4\pi\nu_m R^2t\right)^{-1/2}\int_{-\infty}^{\infty}H_\infty d\zeta'\left[-\frac{(\zeta-\zeta'+\omega t-\omega_T t)^2}{4\nu_m R^2t}\right] \qquad (8)$$

Proportionately $H_\chi(\nabla T)^2$. Therefore, less $H_\perp$. When determining the electric field, the particle with a Larmor frequency $\Omega(t)$ moving in a homogeneous magnetic field, when attenuation, the equation will be in the following form

$$m\frac{dV}{dt}=e\vec{E}+\frac{e}{C}\left[\vec{V}\vec{H}\right]-\frac{1}{2}m\nu\vec{V} \tag{9}$$

$$rot\vec{E}=-\frac{1}{C}\frac{\partial\vec{H}}{\partial t}\quad,\qquad \vec{E}=-2\left[\frac{1}{C}\frac{\partial\vec{H}}{\partial t}\vec{V}H\right]$$

V - Double vector.

$$\frac{\partial\vec{V}}{\partial t}=-\frac{2e}{mc}\left[\frac{\partial\vec{H}}{\partial t}V\right]+\frac{e}{mc}\left[V\vec{H}\right]-\frac{1}{2}V\vec{V} \tag{10}$$

or $\frac{e}{mC}\frac{\partial\vec{H}}{\partial t}=\Omega(t)$, here Ω - Larmor frequency.

$$\Omega=\frac{eH}{mC}\quad,\qquad H\ -\ H_z$$

$$\ddot{x}=-2\left[\vec{\Omega}(t)V\right]_x+\left[\vec{V}\vec{\Omega}\right]_x-\frac{1}{2}V\dot{x}$$

$$\left.\begin{aligned}\ddot{x}&=2\dot{\Omega}y+\dot{y}\Omega-\frac{1}{2}V\dot{x}\\ \ddot{y}&=-2\dot{\Omega}x-\Omega x-\frac{1}{2}Vy\end{aligned}\right\}\qquad z=x+iy \tag{11}$$

$$\ddot{z}=-2i\Omega z-i\Omega z-\frac{1}{2}V\dot{z}\quad \text{or}$$

$$\ddot{z}+i\left[\Omega(t)-i\frac{V}{2}\right]\dot{z}+2i\dot{\Omega}z=0 \tag{12}$$

The coordinate $z=x+iy$ and density of the particle perpendicular to the magnetic field. ν is Frequency of attenuation.

$$\Omega(t)=\Omega_0+\Omega_1\cos\omega t=\Omega_0\left[1+h\cos\Omega_0(1+\Delta)t\right]\quad,\qquad \Delta<<1$$

CONCLUSIONS

Thus, at ∇T the analytical expression for a magnetic field created by hydrodynamic motion was obtained. The frequency of the Larmor was calculated by this meaning. In longitudinal and transverse waves, analytical expressions of the magnetic field are different.

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Received: 25.10.2021