SI

RCGS

Maxwell

SI	RCGS
$\mathrm{div}\,\underline{B} = 0$	$\mathrm{div}\,\underline{B} = 0$
$\mathrm{div}\,\underline{D} = \rho$	$\mathrm{div}\,\underline{D} = \rho$
$\mathrm{rot}\,E = -\frac{\partial B}{\partial t}$	$\mathrm{rot}\,E = -\frac{1}{c}\frac{\partial B}{\partial t}$
$\mathrm{rot}\,H = \frac{\partial D}{\partial t} + j$	$\mathrm{rot}\,H = \frac{1}{c}\left(\frac{\partial D}{\partial t} + j\right)$

Anyagi

SI	RCGS
$\underline{D} = \varepsilon E = \varepsilon_0 \varepsilon_r \underline{E}$	$D = \varepsilon E$
$H = \frac{1}{\mu} B = \frac{1}{\mu_0 \mu_r} B$	$H = \frac{1}{\mu} B$

Lorentz-erő

SI	RCGS
$m\ddot{r} = Q\,(E + v \times B)$	$m\ddot{r} = Q\left(\underline{E} + \frac{1}{c} v \times \underline{B}\right)$

Sebesség

$v = \frac{1}{\sqrt{\varepsilon\mu}} = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}\frac{1}{\sqrt{\varepsilon_r \mu_r}}$

$n = \sqrt{\varepsilon_r \mu_r}$

$c_0 \quad \frac{1}{n}$

$H = \sqrt{\frac{\varepsilon_0}{\mu_0}}\, E$

vák

$D = \varepsilon_0 E$

$H = \frac{1}{\mu_0} B$

$v = \frac{c}{n} = \frac{c}{\sqrt{\varepsilon\mu}}$

$H = E = B = D$

$D = E$

$H = B$

$N \quad \frac{1}{m^3}$

$e > 0$

elektron

$-e$

$\rho = 0$

$\underline{j} = -Ne\underline{v}$

Síkhullám

$$\underline{E}(\underline{r},t) = \underline{E}_0\, e^{i(\underline{k}\underline{r}-\omega t)} \qquad \underline{r}(t) = \underline{r}_0\, e^{i(\underline{k}\underline{r}-\omega t)}$$

$$\underline{B} = \underline{B}_0 \quad -\text{''}- \qquad \underline{j} = \underline{j}_0\, e^{\cdots}$$

$$\frac{\partial}{\partial t} \longrightarrow -i\omega \qquad \underline{\nabla} \sim i\underline{k} \qquad V = \frac{\omega}{|k|}$$

$$\text{rot}\, \underline{E} \sim i\underline{k}\times \underline{E}_0\, e^{\cdots} \qquad \frac{\omega}{kc} = \frac{V}{c} = \frac{1}{n}$$

$$\text{div}\, \underline{E} \qquad i\underline{k}\underline{E}_0\, e^{\cdots}$$

Mx 1 $\quad \text{div}\, \underline{B} = \underline{\nabla}\underline{B} = 0 \quad \Rightarrow i\underline{k}\underline{B}_0 = 0$

Mx 2 $\quad \text{div}\, \underline{E} = \rho = 0 \qquad i\underline{k}\underline{E}_0 = 0$

Mx 3 $\quad \text{rot}\, \underline{E} = -\frac{1}{c}\frac{\partial \underline{B}}{\partial t} \qquad i\underline{k}\times\underline{E}_0 = -\frac{1}{c}(-i\omega)\underline{B}_0$

$$\boxed{\underline{k}\times\underline{E}_0 = \frac{\omega}{c}\underline{B}_0}$$

$$\underline{k}\times(\underline{k}\times\underline{E}_0) = \underline{k}\underbrace{(\underline{k}\underline{E}_0)}_{0} - \underline{E}_0(\underline{k}\underline{k}) = -\underline{E}_0 k^2 = \frac{\omega}{c}\underline{k}\times\underline{B}_0 \qquad \boxed{\underline{k}\times\underline{B}_0 = -\frac{k^2 c}{\omega}\underline{E}_0}$$

Mx 4 $\quad \text{rot}\, \underline{H} = \text{rot}\, \underline{B} = \frac{1}{c}\left(\frac{\partial \underline{D}}{\partial t} + \underline{j}\right)$ $\quad E$

$$i\underline{k}\times\underline{B}_0 = \frac{1}{c}\left(-i\omega\underline{E}_0 + \underline{j}_0\right)$$

$$\underline{k}\times\underline{B}_0 = -\frac{\omega}{c}\underline{E}_0 + \frac{1}{ic}\underline{j}$$

$$\frac{i\underline{j}_0}{c} = -\frac{\omega}{c}\underline{E}_0 - \underline{k}\times\underline{B}_0 = \frac{k^2 c}{\omega}\underline{E}_0 - \frac{\omega}{c}\underline{E}_0$$

$$= \left(\frac{k^2 c}{\omega} - \frac{\omega}{c}\right)\underline{E}_0$$

$$i\underline{j}_0 = \omega\left(\underbrace{\frac{k^2c^2}{\omega^2}}_{n^2} - 1\right)\underline{E}_0$$

$$\boxed{\omega(n^2-1)\underline{E}_0 = i\underline{j}_0}$$

$$\underline{j} = -Ne\underline{v} = -Ne\dot{\underline{r}} \qquad \omega(n^2-1)\underline{E}_0 = -Ne\omega r_0$$

$$\underline{r} = \underline{r}_0\, e^{i(kr-\omega t)}$$

$$\underline{v} = -i\omega\underline{r}_0\, e^{\sim} \qquad \boxed{\underline{r}_0 = \frac{1-n^2}{N\omega}\underline{E}_0}$$

$$\underline{j} = \underbrace{iNe\omega r_0}_{j_0}\, e^{\sim} \qquad n = \frac{ck}{\omega}$$

① plasma

$$m\ddot{\underline{r}} = -e\underline{E}$$

$$\underline{r} \sim \underline{r_0} e^{-i\omega t}$$

$$\ddot{r} = -\omega^2 r_0 e^{-i\omega t}$$

$$-m\omega^2 \underline{r_0} = -e\underline{E_0}$$

$$r_0 = \frac{1-n^2}{Ne}\underline{E_0} = \frac{e}{m\omega^2}\underline{E_0}$$

$$1-n^2 = \frac{Ne^2}{m\omega^2}$$

$$\Omega_p^2 = \frac{Ne^2}{m}$$

$$1-n^2 = \frac{\Omega_p^2}{\omega^2}$$

$$n^2 = 1-\frac{\Omega_p^2}{\omega^2} < 1$$

$$n = \frac{ck}{\omega}$$

$$\frac{c^2k^2}{\omega^2} - 1 = \frac{\Omega_p^2}{\omega^2}$$

$$c^2k^2 - \omega^2 = \Omega_p^2$$

$$\omega^2 - c^2k^2 = -\Omega_p^2$$

$$\frac{\partial^2 u}{\partial t^2} = c^2\Delta u - \mu^2 u$$

Klein-Gordon

$$\boxed{\omega > \Omega_p}$$

$$V_f = \frac{\omega}{k}$$

$$\omega = \sqrt{c^2k^2 + \Omega_p^2}$$

$$V_f = \frac{\omega}{k} = \sqrt{c^2 + \frac{\Omega_p^2}{\omega^2}} > c$$

$$V_g = \frac{d\omega}{dk} = \frac{c^2k}{\sqrt{c^2k^2+\Omega_p^2}}$$

$$V_g V_f = c^2$$

$$V_g < c$$

$\Omega_p(r)$

$\omega > \Omega_p \qquad \Omega_p^2 = \frac{Ne^2}{m}$

② Szigetelő

$$m\ddot{\underline{r}} = -D\underline{r} - e\underline{E}$$

$$D = m\omega_0^2 \qquad \omega_0 = \sqrt{\frac{D}{m}}$$

$$\omega_0 \gg \omega$$

$$-m\omega^2 \underline{r}_0 = -m\omega_0^2 \underline{r}_0 - e\underline{E}_0$$

$$m(\omega_0^2 - \omega^2)\underline{r}_0 = -e\underline{E}_0$$

$$\underline{r}_0 = \frac{1-n^2}{Ne}\underline{E}_0$$

$$\underline{r}_0 = \frac{-e\underline{E}_0}{m(\omega_0^2-\omega^2)} = \frac{1-n^2}{Ne}\underline{E}_0$$

$$1-n^2 = -\frac{Ne^2}{m(\omega_0^2-\omega^2)} = -\frac{\Omega_p^2}{\omega_0^2-\omega^2}$$

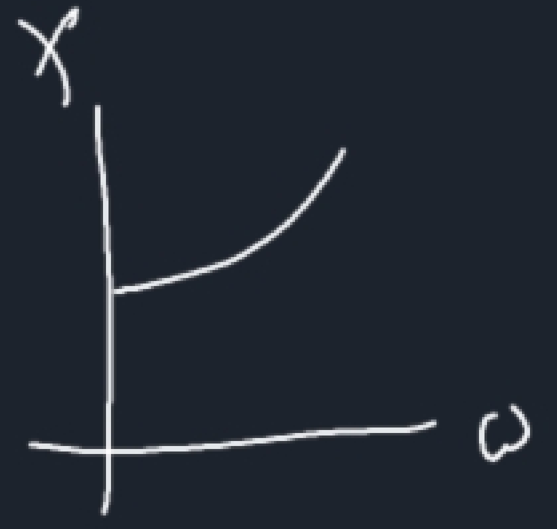
$$\boxed{n^2 = 1 + \frac{\Omega_p^2}{\omega_0^2-\omega^2}} \qquad n_0^2 = 1 + \frac{\Omega_p^2}{\omega_0^2}$$

$$\varepsilon - 1 = \chi = \frac{\Omega_p^2}{\omega_0^2-\omega^2}$$

$$n^2 = \varepsilon\mu$$

$$\chi = \frac{\Omega_p^2}{\omega_0^2\left(1-\frac{\omega^2}{\omega_0^2}\right)} \sim \frac{\Omega_p^2}{\omega_0^2}\left(1+\frac{\omega^2}{\omega_0^2}\right)$$

$$(1+\varepsilon)^n \sim 1+n\varepsilon \qquad \approx \chi_0 + \frac{\Omega_p^2}{\omega_0^4}\omega^2$$



$$\boxed{\Omega_c = \frac{eH}{mc}}$$

$H \gg E_0$

$\beta = \pm 1$

$\underline{B} = \begin{pmatrix} 0 \\ 0 \\ \beta H \end{pmatrix}$

$$m\ddot{\underline{r}} = -\frac{e}{c}\,\dot{\underline{r}} \times \underline{H}$$

$$\underline{r}(t) = R\begin{pmatrix} \cos\omega t \\ -\alpha \sin\omega t \\ 0 \end{pmatrix}$$

$$\alpha = \pm 1$$

$$\dot{\underline{r}} = R\begin{pmatrix} -\omega \sin\omega t \\ -\alpha\omega \cos\omega t \\ 0 \end{pmatrix}$$

$$\dot{r} \times \underline{B} = R\omega\begin{pmatrix} -\sin\omega t \\ -\alpha \cos\omega t \\ 0 \end{pmatrix} \times \beta H \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}$$

$$= \beta H \alpha R\omega \begin{pmatrix} \cos\omega t \\ -\alpha \sin\omega t \\ 0 \end{pmatrix}$$

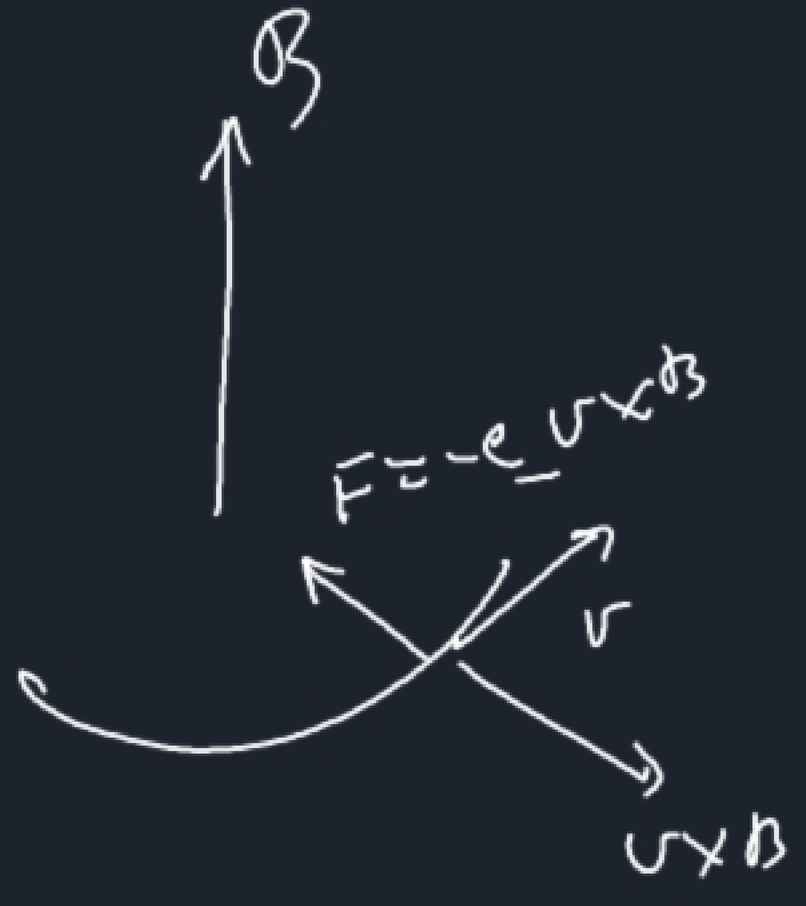
$$\ddot{r} = -\omega^2 r$$

$$-m\omega^2 R\begin{pmatrix} \cos\omega t \\ -\alpha \sin\omega t \\ 0 \end{pmatrix} = -\frac{e}{c}\alpha\beta H R\omega \begin{pmatrix} \\ \\ \end{pmatrix}$$

$$\omega = \underbrace{\frac{eH}{mc}}_{\Omega_c}(-\alpha\beta)$$

$$\Omega_L = \frac{eH}{2mc}$$

Larmor



$$\frac{mv^2}{R}$$

$B = \rho H$

$\rho = \pm 1$

$E_x = E_0 \cos(kz - \omega t)$

$E_y = \alpha E_0 \sin(kz - \omega t)$

$\alpha = \pm 1$

$\alpha = -1$ gobbra

$\hat{E} = E_x + i E_y = E_0 \, e^{i\alpha(kz - \omega t)}$

$\hat{B}$

$\hat{r} = x + iy$

$\hat{v}$

$\hat{a} =$

$\dot{r} \times B = + \alpha \rho H \omega \hat{r}$

$m \underline{\ddot{r}} = -e \underline{E} - \frac{e}{c} \dot{r} \times B$

$- m\omega^2 \hat{r} = -e \hat{E} - \alpha\rho \frac{eH}{c} \hat{r} \omega$

$\omega \left(\omega - \alpha\rho \frac{eH}{cm} \right) \hat{r} = \frac{e}{m} \hat{E}$

$1 - n^2 = \frac{\Omega_p^2}{\omega^2 - \alpha\rho\, \omega \Omega_c}$

$\underline{\hat{r}} = \frac{1-n^2}{Nm} \hat{E}$

$ij \sim E$

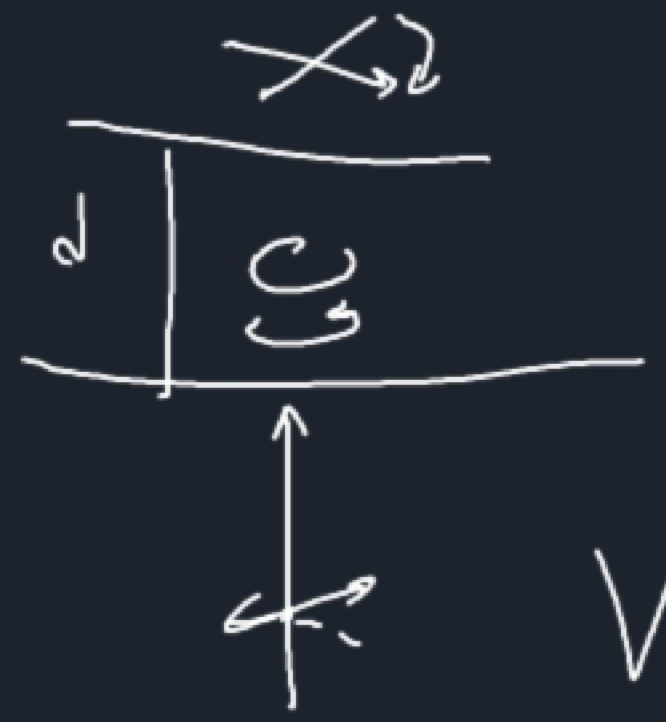
$\Omega_p^2 = \frac{Ne^2}{m}$

$\perp$ circ pol

$\parallel k$

$$m\ddot{\underline{r}} = -m\omega_0^2\underline{r} - e\underline{E} - \frac{e}{c}\dot{\underline{r}}\times\underline{B}$$

$$n^2 = 1 + \frac{\Omega_p^2}{\omega_0^2 - \omega^2 - 2p\,\omega\,\Omega_c}$$



$$\vartheta = dHV$$

Verdet

$$V = \frac{e}{2mc^2}\,\omega\left(\frac{d}{d\omega}n_0(\omega)\right)$$