II .1- $u_1 = -p_0 E \qquad u_2 = p_0 E$

2/ $N_1 = N \dfrac{\exp + \frac{p_0 E}{kT}}{\exp \frac{p_0 E}{kT} + \exp - \frac{p_0 E}{kT}}$ c $\qquad N_2 = N \dfrac{\exp - \frac{p_0 E}{kT}}{\exp \frac{p_0 E}{kT} + \exp - \frac{p_0 E}{kT}}$

-2- $P = (N_1 - N_2)\, p_0$

2/ $\vec{P} = N p_0 \operatorname{th}\left(\dfrac{p_0 E}{kT}\right) \cdot \left(\dfrac{\vec{E}}{\|\vec{E}\|}\right)$ ⇐ normalisat.

$\frac{p_0 E}{kT}$

-3- $p_0 E \ll kT$ x petit

2/ $\vec{P} \simeq \dfrac{N p_0^2 \vec{E}}{kT} = \varepsilon_0 \chi \vec{E}$

$$\boxed{\chi = \frac{N p_0^2}{\varepsilon_0 kT}.}$$

III ① $\frac{dP}{dt} + \frac{P}{\tau} = \frac{\chi_s \varepsilon_0}{\tau} E_0$

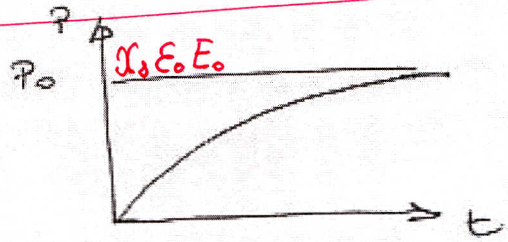
$\frac{dP}{dt} = -\frac{P}{\tau}$ $\quad \vec{P} = \vec{cte}\ \exp -\frac{t}{\tau}.$

solution gale

$\frac{dP}{dt} = 0 \quad \vec{P}_0 = \chi_s \varepsilon_0 \vec{E_0}$ $\quad\quad \vec{P} = \chi_s \varepsilon_0 \vec{E_0} + \vec{cte}\ \exp -\frac{t}{\tau}$

$t = 0 \quad \vec{P} = \vec{0} \quad\quad \vec{cte} = -\chi_s \varepsilon_0 \vec{E_0}$

2 $\Rightarrow$ $\boxed{\vec{P} = \chi_s \varepsilon_0 \vec{E_0} \left(1 - \exp -\frac{t}{\tau}\right)}$



τ cte de tps caractéristique du processus de polarisation.

② - a - $\vec{J}_{in} = \frac{\partial \vec{P}}{\partial t}$ 1

- b - $\frac{dP}{dV} = \frac{\partial \vec{P}}{\partial t} \cdot \vec{E} = +\frac{\chi_s \varepsilon_0 E_0^2}{\tau} \exp -\frac{t}{\tau}$ 1

$\int_0^\infty e^{-t/\tau} dt$

brusque

$\Delta E_1 = V \int_0^\infty \frac{dP}{dV}\, dt = \frac{V \chi_s \varepsilon_0}{\tau} E_0^2\ \tau \left[-\exp -\frac{t}{\tau}\right]_0^\infty$

$\boxed{\Delta E_1 = V \chi_s \varepsilon_0 E_0^2}$

- c - $\vec{P} = \chi_s \varepsilon_0 \vec{E}(t)$ 1

$\vec{J} = \chi_s \varepsilon_0 \frac{d\vec{E}}{dt} \quad\quad \frac{dP}{dV} = \chi_s \varepsilon_0 \vec{E} \frac{d\vec{E}}{dt}$

$= \chi_s \varepsilon_0 \frac{1}{2} \frac{dE^2}{dt}$

quasi-statique.

$\Delta E_2 = V \int_0^{E_0} \frac{\chi_s \varepsilon_0}{2} \frac{dE^2}{dt} dt = \boxed{\frac{V \chi_s \varepsilon_0 E_0^2}{2}.}$

Cas réversible, pas d'énergie "perdue".

Magnétisme

$r < a$, $r > b$ | vides $\qquad \vec{M} = \beta \dfrac{\vec{r}}{4\pi r^3} \qquad \beta > 0$

1) Densité volumique

$$\vec{j}_m = \vec{rot}\,\vec{M} = \frac{\beta}{4\pi}\,\vec{rot}\left(\frac{\vec{r}}{r^3}\right) = \frac{\beta}{4\pi}\,\vec{rot}\left(\frac{\vec{u}}{r^2}\right)$$

$$= \frac{\beta}{4\pi}\,\vec{rot}\left(-\vec{grad}\left(\frac{1}{r}\right)\right) = \vec{0}$$

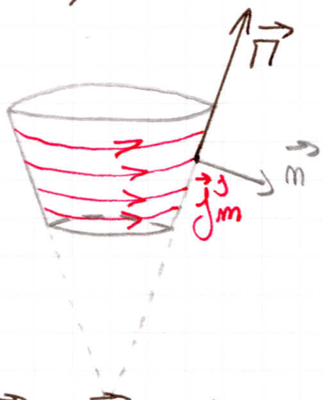
$$\vec{j}_m^{\,s} = \vec{M} \wedge \frac{\vec{r}}{r} = \beta\frac{\vec{r}}{4\pi r^3} \wedge \frac{\vec{r}}{r} = \vec{0}$$

2) Potentiel vecteur $\quad \vec{A} = \dfrac{\mu_0}{4\pi}\left(\iiint \dfrac{\vec{j}_m}{r}\,d\tau + \iint \dfrac{\vec{j}_m^{\,s}}{r}\,dS\right) = \vec{0}$

Champ magnétique $\quad \vec{B} = \dfrac{\mu_0}{4\pi}\left(\iiint \dfrac{\vec{j}_m \wedge \vec{r}}{r^3}\,d\tau + \iint \dfrac{\vec{j}_m^{\,s} \wedge \vec{r}}{r^3}\,dS\right) = \vec{0}$.

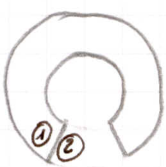
excitation magnétique $\quad \vec{H} = \dfrac{\vec{B}}{\mu_0} - \vec{M} = -\vec{M} = -\beta\dfrac{\vec{r}}{4\pi r^3}$

3) $\vec{j}_m^{\,s} = \vec{M} \wedge \vec{n}$



$$|\vec{j}_m^{\,s}| = \frac{\beta}{4\pi r^2} = |\vec{M}|$$

Champ magnétique dans le tore $\quad \vec{B} = \mu_0 \vec{H}$



A l'interface du tore $\quad \vec{H}_{T_1} - \vec{H}_{T_2} = \vec{0}$ (continuité) $\qquad \vec{H}_{T_2} = \vec{H}_{T_1} = -\beta\dfrac{\vec{r}}{4\pi r^3}$

$$\Rightarrow \vec{B} = -\mu_0\,\beta\frac{\vec{r}}{4\pi r^3}$$