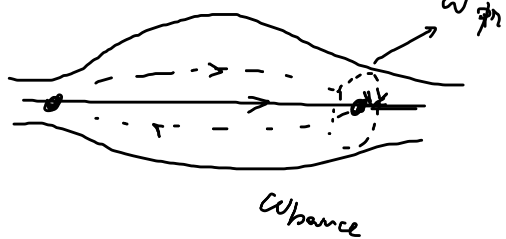
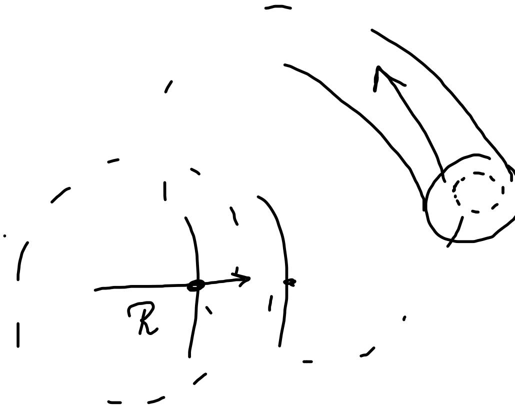
$d + t \to n + {}^4He$

$E_\alpha \sim 3.5\ \text{MeV}$

$T_d \sim T_t \sim 10-20\ \text{keV}$



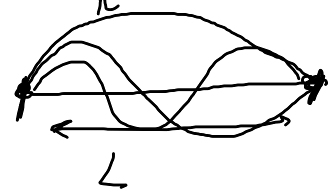

$\omega = k_\parallel v_A$

$v_A^2 = \frac{B_0^2}{\mu_0 \rho_0}$

$B_0 \propto \frac{1}{R}$

$L = n \frac{\lambda}{2}$

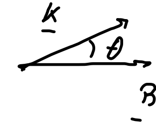
$k_\parallel (n, m)$


→ discr.

$\omega_n$

Due fluidi $B \neq 0$ $\quad T = 0$




$$n^2 = \frac{B \pm \sqrt{B^2 - 4AC}}{2A}$$

$$A = S \,\mathrm{sen}^2\theta + P\cos^2\theta$$

$$B = (S^2 - D^2)\,\mathrm{sen}^2\theta + PS(1+\cos^2\theta)$$

$$C = PRL$$

$$n = n(\theta)$$

$$R = 1 - \sum_\alpha \frac{\omega_{p\alpha}^2}{\omega(\omega + \omega_{c\alpha})}$$

$$L = 1 - \sum_\alpha \frac{\omega_{p\alpha}^2}{\omega(\omega - \omega_{c\alpha})}$$

$$S = \frac{R+L}{2} \qquad D = \frac{R-L}{2}$$

$$P = 1 - \sum_\alpha \frac{\omega_{p\alpha}^2}{\omega^2} \qquad \omega_c \propto \frac{1}{m}$$

$$\omega_{p\alpha}^2 = \frac{n_\alpha e^2}{\varepsilon_0 m_\alpha} \qquad \omega_{c\alpha} = \frac{q_\alpha B}{m_\alpha}$$

CMA Clemmow Mullaly Allis

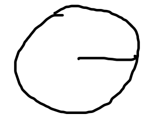
$$v_f = \frac{c}{n(\theta)}$$

$\omega_c \propto B$ ; $\omega_p \propto n$

$n = n(\theta)$

es onde nel vuoto e.m.

$$\frac{\omega}{k} = c \; ; \; n = \frac{c}{v_f} = \frac{ck}{\omega} = 1$$



Se $T \neq 0$ → modifica di $\omega = \omega(k)$
→ nuove onde (es. onde di Bernstein)

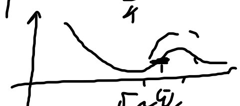
Smorzamento di Landau $\frac{\omega}{k} \sim v_{th}$

Distr. Maxwell

Se $\left.\frac{\partial f}{\partial v}\right|_{v=\frac{\omega}{k}} < 0$ Onda è smorzata

Più cariche con $v_z < \frac{\omega}{k}$

$v \sim \frac{\omega}{k}$



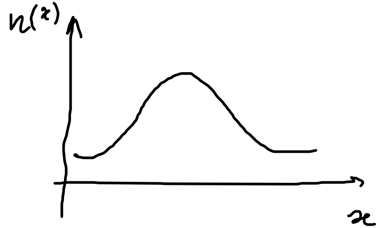
$v \sim \omega/k$

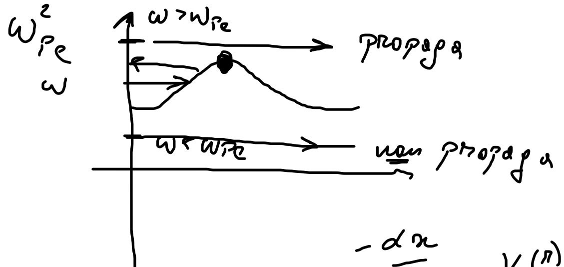
$\left.\frac{\partial f}{\partial v}\right|_{v=\frac{\omega}{k}} > 0$ Onda è ampl.

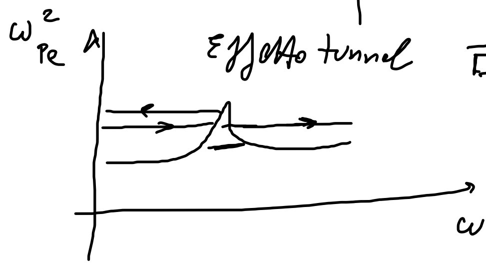
# Plasmi disomogenei ed effetto tunnel

$\omega^2 = c^2 k^2 + \omega_{pe}^2$ Se $\omega < \omega_{pe}$ : onda evanescente

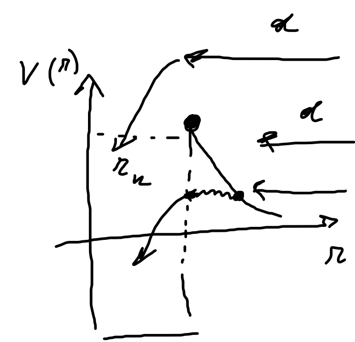
$\omega > \omega_{pe}$ : → propaga $\omega_{pe}^2 = \frac{n e^2}{m \varepsilon_0}$

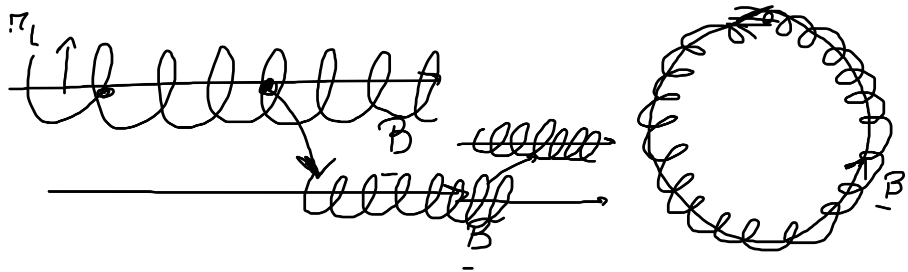



Effetto tunnel $T \propto e^{-\frac{\alpha x}{L}}$






# Modello 1D della diffusione


a $t=0$ tutte le part. sono a $x=0$

$\langle x(t)\rangle = ?$ $\quad \langle \sigma^2 \rangle = ?$

$\tau$: tempo tra due collisioni

$\Delta x$: spostamento a causa di una collisione

egualmente distribuita a DX o SX

Ci aspettiamo

$\langle x(t)\rangle = 0$

$\langle \sigma^2 \rangle \neq 0$

Sono state fatte $N$ collisioni

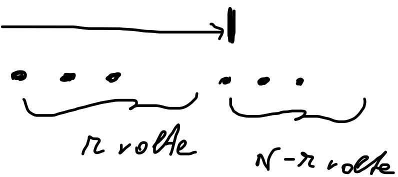
$r$ collisioni a DX, $\quad r \le N$

$N-r$ collisioni a SX

$$x(r) = \underbrace{r\cdot\Delta x}_{\text{spost. a DX}} - \underbrace{(N-r)\,\Delta x}_{\text{spost. SX}} = (2r-N)\,\Delta x$$

$r$ collisioni a DX

$N-r$ " " SX




$$\left(\frac{1}{2}\right)^{r} \qquad \left(\frac{1}{2}\right)^{N-r}$$

$$\left(\frac{1}{2}\right)^{r}\left(\frac{1}{2}\right)^{N-r} = \frac{1}{2^N}$$

# modi in cui scegliere $r$ spost. a DX tra $N$ totali $= \binom{N}{r} = \dfrac{N!}{r!\,(N-r)!}$

$$P_r = \binom{N}{r}\cdot\frac{1}{2^N}$$

$$\langle x \rangle = \sum_{r=0}^{N} x(r) P_r = \sum_{r=0}^{N} \underbrace{(2r-N)\Delta x}_{x(r)} \binom{N}{r} \frac{1}{2^N} =$$

$$= \frac{\Delta x}{2^N} \underbrace{\sum_{r=0}^{N} (2r-N) \binom{N}{r}} = \frac{\Delta x}{2^{N-1}} \sum_{r=0}^{N} \left(r - \frac{N}{2}\right) \binom{N}{r}$$

$$F_N(y) = \frac{(1+y)^N}{2^N y^{N/2}} = \frac{\sum_{r=0}^{N} \binom{N}{r} y^r (1)^{N-r}}{2^N y^{N/2}} = \frac{1}{2^N} \sum_{r=0}^{N} \binom{N}{r} y^{r-\frac{N}{2}}$$

$$(a+b)^N = \sum_{r=0}^{N} \binom{N}{r} a^r b^{N-r}$$

$$\left.\frac{dF_N(y)}{dy}\right|_{y=1} = \frac{1}{2^N} \sum_{r=0}^{N} \binom{N}{r} \left(r - \frac{N}{2}\right) \left. y^{r-\frac{N}{2}-1} \right|_{y=1}$$

$$= \frac{1}{2^N} \sum_{r=0}^{N} \binom{N}{r} \left(r - \frac{N}{2}\right)$$

$$\frac{dF_N}{dy} = \frac{1}{2^N} \left. \frac{N(1+y)^{N+1} - \frac{N}{2}\,\frac{(1+y)^N}{y}}{y^N} \right|_{y=1} = 0$$

$$\langle x \rangle = 0 \qquad \sigma^2 = \langle x^2 \rangle - (\langle x \rangle)^2$$

$$\langle x \rangle = 0$$

$$\langle \sigma^2 \rangle = \langle x^2 \rangle$$

$$\langle x^2 \rangle = \sum_{r=0}^{N} x^2(r) P_r = \sum_{r=0}^{N} (\Delta x)^2 (2r - N)^2 \binom{N}{r} \frac{1}{2^N} =$$

$$= \frac{(\Delta x)^2}{2^N} \sum_{r=0}^{N} \binom{N}{r} (2r - N)^2 = \frac{4 (\Delta x)^2}{2^N} \sum_{r=0}^{N} \binom{N}{r} \left(r - \frac{N}{2}\right)^2$$

$$F_N = \frac{(1+y)^N}{2^N y^{N/2}} = \frac{1}{2^N} \sum_{r=0}^{N} \binom{N}{r} y^{r-N/2}$$

con l'esp.

$$y \frac{d}{dy}\left( y \frac{dF_N}{dy} \right)\Bigg|_{y=1} = \dots = \frac{\sum_{r=0}^{N} \binom{N}{r} \left( r - \frac{N}{2} \right)^2}{2^N}$$

// senza esp.

$$\frac{N}{4}$$

$$\langle x^2 \rangle = N \cdot (\Delta x)^2 \neq 0$$

$\tau$

$$t = \underline{N \cdot \tau} \; ; \; N = t/\tau \qquad \langle x^2 \rangle = t \frac{(\Delta x)^2}{N}$$

$$\sigma = \sqrt{\langle x^2 \rangle} \propto \sqrt{t}$$