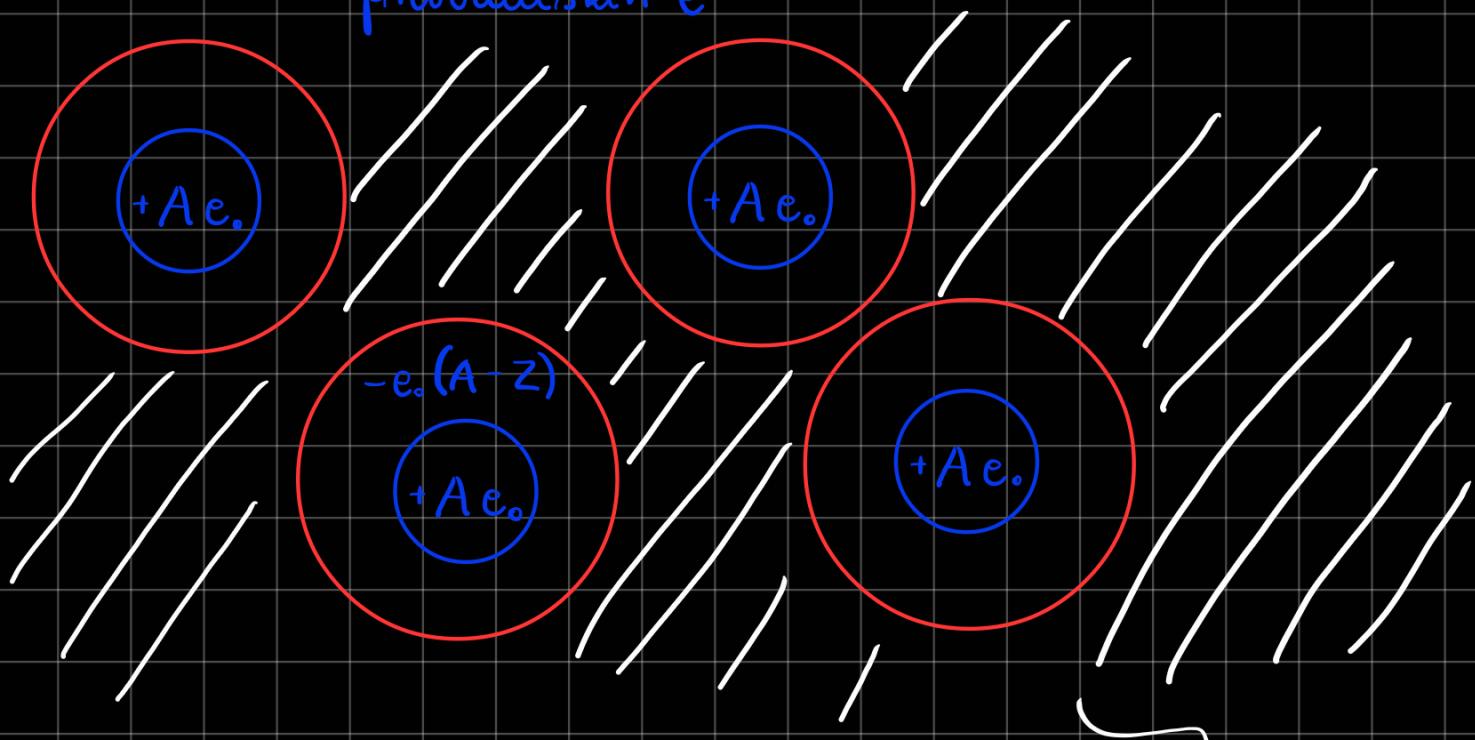


## Družiščni model

Model prevodnika, mostly wrong, nekatere enostavne lastnosti so super ↓

prevodniških  $e^-$



$A \dots \text{č. n.}$ ,  $Z \dots \text{č. val. e}^-$

el. plin

Zelimo določiti gibalno enačbo za el. plin.

$$d\vec{p} = \vec{F} dt$$

$e^-$  trčejo ≈ jedri, verjetno na trk  $\frac{dt}{\tau}$ ,  $\tau \dots$  relaksacijski čas

Trke obravnavamo kot pravne

$t \neq 0$ :  $\langle \vec{p}(t) \rangle = 0$ , in  $\vec{E} = 0$ ,  $e^-$  se gibljejo v razmeri, nobena ni priviligerana, zato je povp.  $\emptyset$

$$\langle \vec{p}(t) \rangle \neq 0 \quad \vec{E} \neq 0$$

$$t = dt$$

$$\langle \vec{p}(t+dt) \rangle = \left(1 - \frac{dt}{\gamma}\right) \langle \vec{p}(t) \rangle + \frac{dt}{\gamma} \cdot \vec{\phi}$$

xa toliko se spremeni  $\vec{p}$   
negativne predznak  
xacitua  $\langle \vec{p} \rangle$  sume k

verjetnost, da mi bilo trka

$$O(dt^2) \doteq 0$$

verjetnost,  
da trk je,  
 $\langle \vec{p} \rangle$  se  
spremeni (?)

$$\frac{\langle \vec{p}(t+dt) \rangle - \langle \vec{p}(t) \rangle}{dt} = -e_0 E - \frac{\langle \vec{p}(t) \rangle}{\gamma}$$

$$\Rightarrow \boxed{\frac{d\langle \vec{p}(t) \rangle}{dt} = -e_0 E - \frac{\langle \vec{p}(t) \rangle}{\gamma}}$$

Po nekaj časa : stacionarno stanje

$$\frac{d\langle \vec{p}(t) \rangle}{dt} = 0$$

$$\Rightarrow \langle \vec{p}(t) \rangle = -e_0 E \quad // \text{umerjeno gibanje e-}$$

Znamo nas el. tok  $I \Rightarrow$  gost. el. toka  $j$

$$j = m (-e_0) \langle \vec{v} \rangle, \quad m = \frac{N}{V}$$

$$\text{klasicno } \langle \vec{p} \rangle = m \langle \vec{v} \rangle$$

$$j = \frac{m e_0 \gamma}{m} \vec{E} \quad // \text{pone manu, kako se mora odraziti na } \vec{E}$$

$$\text{El. prenájom vektor } \vec{j} : \boxed{\vec{j} = \sigma \vec{E}}$$

$$\sigma_0 = \frac{m e^2 \gamma}{m}$$

statická (specifická) el. prenájom

5/24 (topic skripta)

$$E = 1 \text{ V/m}$$

$$\mu = 0'0032 \text{ m}^2/\text{V}\cdot\text{s} \quad // \text{závislosť } \mu \text{ od ktorého má } \vec{E}$$

$$E_F = 7'0 \text{ eV} \quad // \text{Fermijeva en.}$$

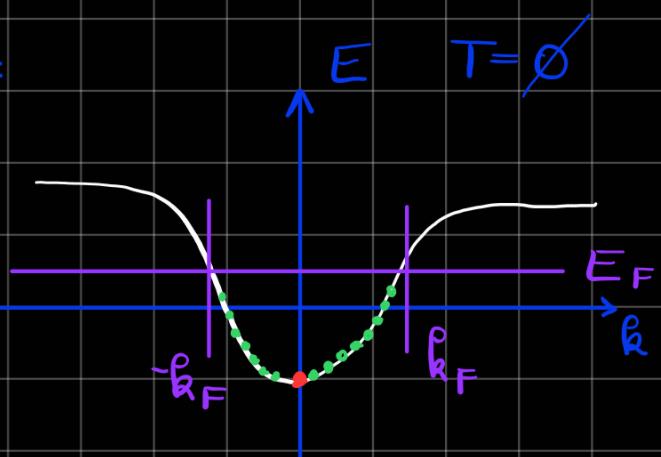
$$\langle \vec{v} \rangle = -\mu \vec{E}$$

$$\langle \vec{v} \rangle = ?$$

$$\frac{\langle \vec{v} \rangle}{v_F} = ?$$

$$\langle \vec{v} \rangle = 0'0032 \text{ m/s}$$

$$E_F :$$



$$k_F = \frac{2\pi}{Na} l, \quad l \in \mathbb{Z}$$

- e<sup>-</sup> xarádajú  
mesta

1. e<sup>-</sup> agre v rôzco tokos, polujeje stanj



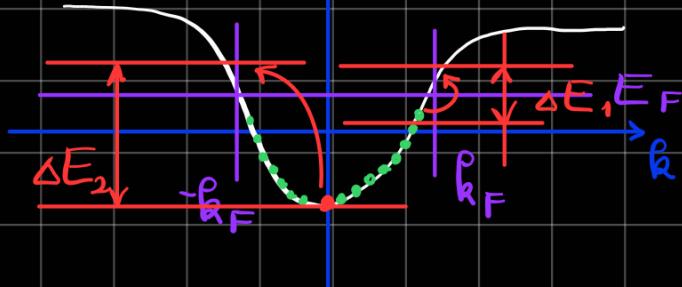
$$Z_{Cu} = Z_{Na} = 1$$

$$\beta_{Cu} = 5'9 \cdot 10^5 / \Omega \text{ m}$$

$$\beta_{Na} = 2'2 \cdot 10^5 / \Omega \text{ m}$$

Povp. prosta pot

$\langle l \rangle = v \tau$ ,  $\tau$  ... povp. čas do trka



$$\Delta E_2 \ll \Delta E_1$$

$e^-$  v blízini  $E_F$  x rýajo ( $\Delta E_1$ ), oaj zo jiu prusta mesta blízu

$$\beta = \frac{m e^2 \tau}{m_e}, \quad \text{S} \rightarrow m - \text{prevodnički el. } \nabla$$

$$\beta = \frac{m}{V}, \quad m_e \ll m_p, \quad m_j \dots \text{masa jadra}$$

$$\beta = \frac{m_j}{V} = \frac{m M}{V} \rightarrow m \dots \text{masa jedinice monci, } M \dots \text{molska masa}$$

$$= \frac{\overline{N} \cdot M}{N_a \cdot V} = n_{at}$$

$$m_{at} = \frac{\beta N_a}{M} \Rightarrow m_{el} = Z m_{at}$$

$$n_{el, Na} = 2 \cdot 5 \cdot 10^{28} / m^3$$

$$n_{el, Cu} = 4 \cdot 5 \cdot 10^{28} / m^3$$

$$N_{nt} = \sum_{\vec{k}} 2 \quad // \text{stauja}$$

$\downarrow$  (degeneracija)

$\forall \vec{k}$  išia dvi dovilkua stauja  $e^-$

$$N_{nt, max} = \sum_{|\vec{k}| \leq k_F} 2 = N_c \quad // \text{uzsima stauja (meja } \vec{k}_F \text{)}$$

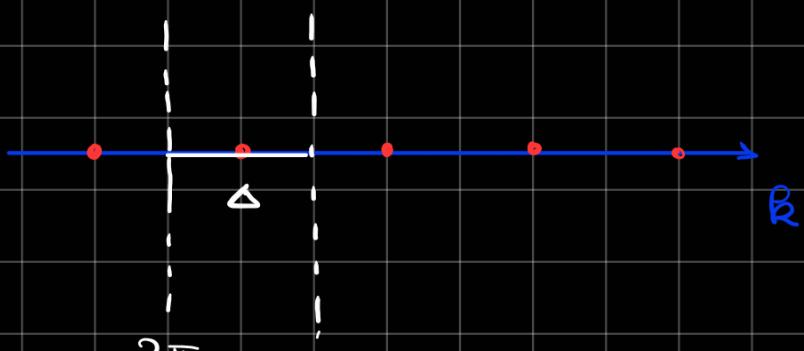
$\downarrow$

$$T = \emptyset$$

Žilius  $\sum \rightarrow \int \frac{d^3k}{\Delta}$ ,  $\Delta$  - Volumen v  $k$ -protozu, kiu prikada določenemu  $k$

Določitev  $\Delta$  v 1D

$$k_\ell = \frac{2\pi}{L} \ell$$



$$\Delta = \frac{2\pi}{L}$$

$$\text{v 3D: } k_{\ell_x, \ell_y, \ell_z} = 2\pi \left( \frac{\ell_x}{L_x}, \frac{\ell_y}{L_y}, \frac{\ell_z}{L_z} \right)$$

$$\Delta = \frac{(2\pi)^3}{V}, \quad V = L_x \cdot L_y \cdot L_z$$

$$N_{el} = 2 \int_0^{\vec{k}_F} \frac{d^3 k}{2\pi} \quad , \quad \vec{k} \leq |\vec{k}_F| \quad \text{v prostoru se tvorí koule}$$

kartesiané koordinate  $\rightarrow$  sférické koordinate

$$N_{el} = \frac{2V}{(2\pi)^3} \frac{4}{3} \pi R_F^3$$

$$n_{el} = \frac{N_{el}}{V} = \frac{R_F^3}{3\pi^2} \Rightarrow R_F = \sqrt[3]{\frac{3\pi^2 n_{el}}{m}}$$

$\hookrightarrow$  vši  $e^-$   napravu  
v uvačbi rax

$$V_F = \frac{\hbar R_F}{m}$$

$$n = \frac{A \rho N_A}{M}, \quad A \dots \text{at. p}^+$$

$$V_{F,Cu} = 1.6 \cdot 10^6 \text{ m/s} \Rightarrow \langle l \rangle_{Cu} = 90 \text{ nm}$$

$$V_{F,Na} = 1.0 \cdot 10^6 \text{ m/s} \Rightarrow \langle l \rangle_{Na} = 30 \text{ nm}$$

#### 4.11 Skripta Zorko

$$\vartheta = 30 \text{ MHz}$$

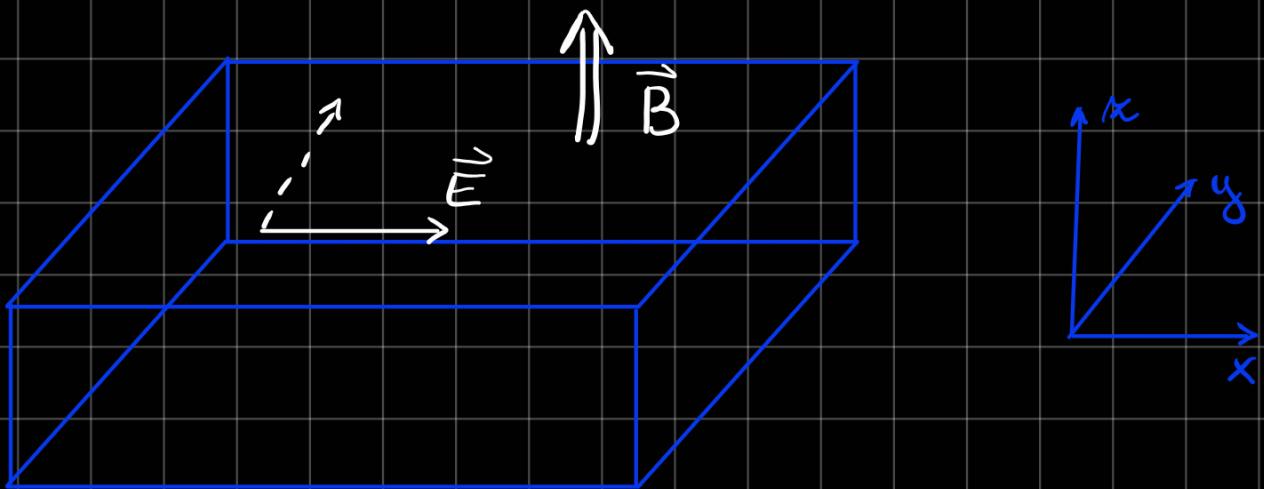
$$M_{Pt} = 195.1 \text{ kg/kmol}$$

$$B_0 = 2 \text{ mT}$$

$$\gamma = 5.1 \cdot 10^{-15} \text{ s}$$

$$\rho_{Pt} = 21.5 \text{ kg/m}^3$$

$$Z_{Pt} = 1$$



$$\vec{B} = B_0 \mathbf{e}_z = \begin{bmatrix} 0 \\ 0 \\ B_0 \end{bmatrix}$$

$$\vec{E} = \begin{bmatrix} E_0 e^{-i\omega t} \\ E_0 e^{-i(\omega t + \delta)} \\ 0 \end{bmatrix}, \quad \delta = -\frac{\pi}{2}$$

$$\vec{E} = E_0 e^{-i\omega t} \begin{bmatrix} 1 \\ i \\ 0 \end{bmatrix}$$

$$\vec{\delta} = \vec{E} - \vec{E}_0 e^{-i\omega t}$$

lasciamo provvedere:

$$\frac{d \langle \vec{p}(t) \rangle}{dt} = - \frac{\langle \vec{p}(t) \rangle}{\gamma} - e_0 (\vec{E} + \langle \vec{v} \rangle \times \vec{B})$$

$\frac{d\vec{\delta}}{dt}$  mas xauima

$$\dot{\vec{\delta}} = -e_0 m \langle \vec{v} \rangle \Rightarrow \langle \vec{v} \rangle = -\frac{\dot{\vec{\delta}}}{m e_0}$$

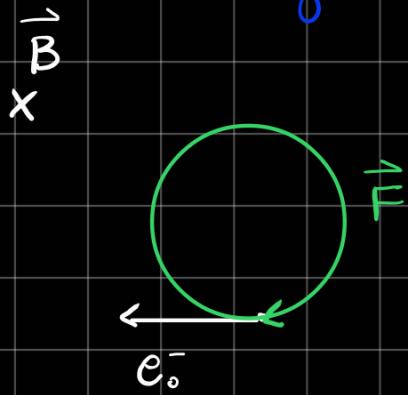
$$\langle \vec{p} \rangle = m \langle \vec{v} \rangle = -\frac{m \dot{\vec{\delta}}}{m e_0}$$

$$\Rightarrow \gamma \frac{d\vec{\delta}}{dt} = -\dot{\vec{\delta}} + \left( \frac{m e_0^2 \gamma}{m} \right) \vec{E} - \left( \frac{e_0 \gamma}{m} \dot{\vec{\delta}} \times \vec{B} \right)$$

wpeljemo:

- staticus prevođenost  $\beta = \frac{m e_0^2 \gamma}{m}$

- ciklotronsko frekvencija  $\omega_c = \frac{v}{r}$



$$F_m = F_{cp}$$

$$e_0 v B_0 = \frac{v^2}{r} m$$

$$\boxed{\omega_c = \frac{e_0 B_0}{m}}$$

$$\dot{\vec{\delta}} \times \vec{c}_x = \begin{bmatrix} \dot{\delta}_{oy} \\ -\dot{\delta}_{ox} \\ 0 \end{bmatrix} .$$

$$\dot{\vec{\delta}} = \dot{\delta}_0 e^{-i\omega t} \Rightarrow \frac{d\vec{\delta}}{dt} = \dot{\delta}_0 (-i\omega) e^{-i\omega t}$$

Po komponutah xapis:

$$x\text{-mer: } -i\omega \gamma j_{ox} = (-j_{ox}) + \beta_0 E_0 - (i\omega_c j_{oy}), \quad (1)$$

$$y\text{-mer: } -i\omega \gamma j_{oy} = (-j_{oy}) + i\beta_0 E_0 + (i\omega_c j_{ox}). \quad (2)$$

$$z\text{-mer: } j_{oz} = 0$$

$$(1) + i(2): (1 - i(\omega + \omega_c)\gamma)(j_{ox} + i j_{oy}) = 0$$

$$\begin{matrix} \text{me manje čiti} \\ \text{nic} \end{matrix} \Rightarrow j_{oy} = i j_{ox}$$

// nizimo v 1. enačbo

$$(1) [1 - i(\omega - \omega_c)\gamma] j_{ox} = \beta_0 E_0.$$

$$\text{spomnimo } \propto \vec{j} = \beta_0 \vec{E}$$

$$\vec{E} \propto e^{-i\omega t}$$

$$\vec{j} \propto e^{-i\omega t}$$

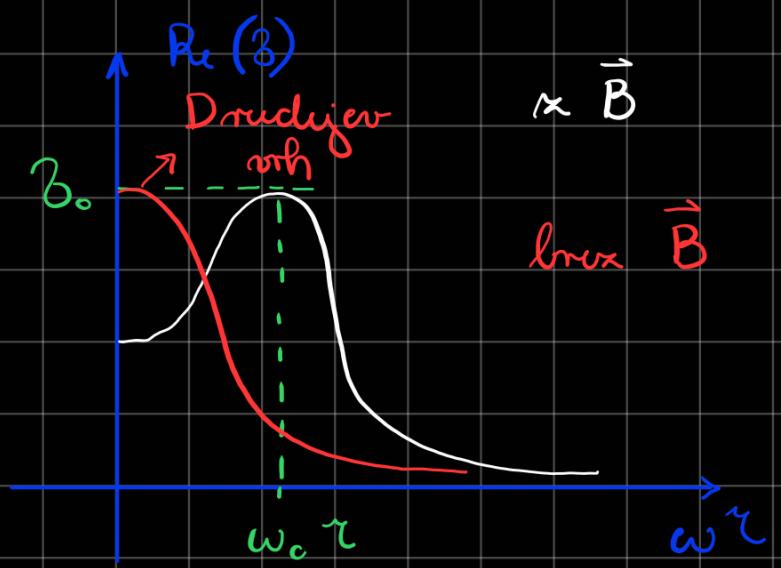
odvis obutiskih e-

$$j_{ox} = \beta_0 E_{ox} \Rightarrow \beta = \frac{\beta_0}{1 - i(\omega - \omega_c)\gamma} = \underbrace{\operatorname{Re}(\beta)}_{\text{pone man}} + i \underbrace{\operatorname{Im}(\beta)}_{\text{koliko en. se izgubi}}$$

// imenovalec realiziramo disipacija en.

$$\beta = \frac{1 + i(\omega + \omega_0)\gamma}{1 + (\omega + \omega_0)^2\gamma^2} \beta_0$$

xaradi absorpcije  
= optična prevodnost



Poprawek