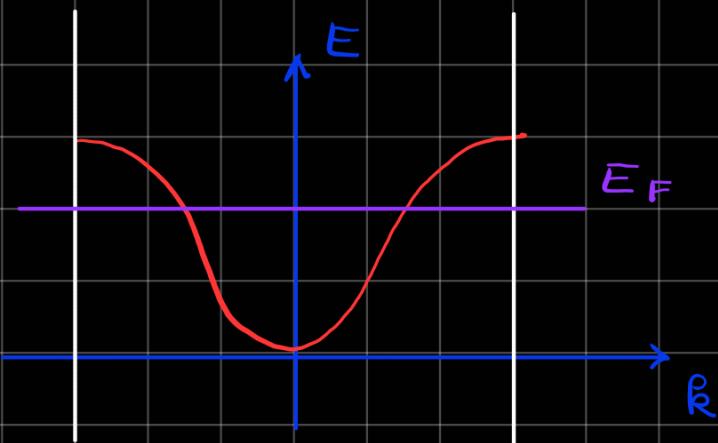
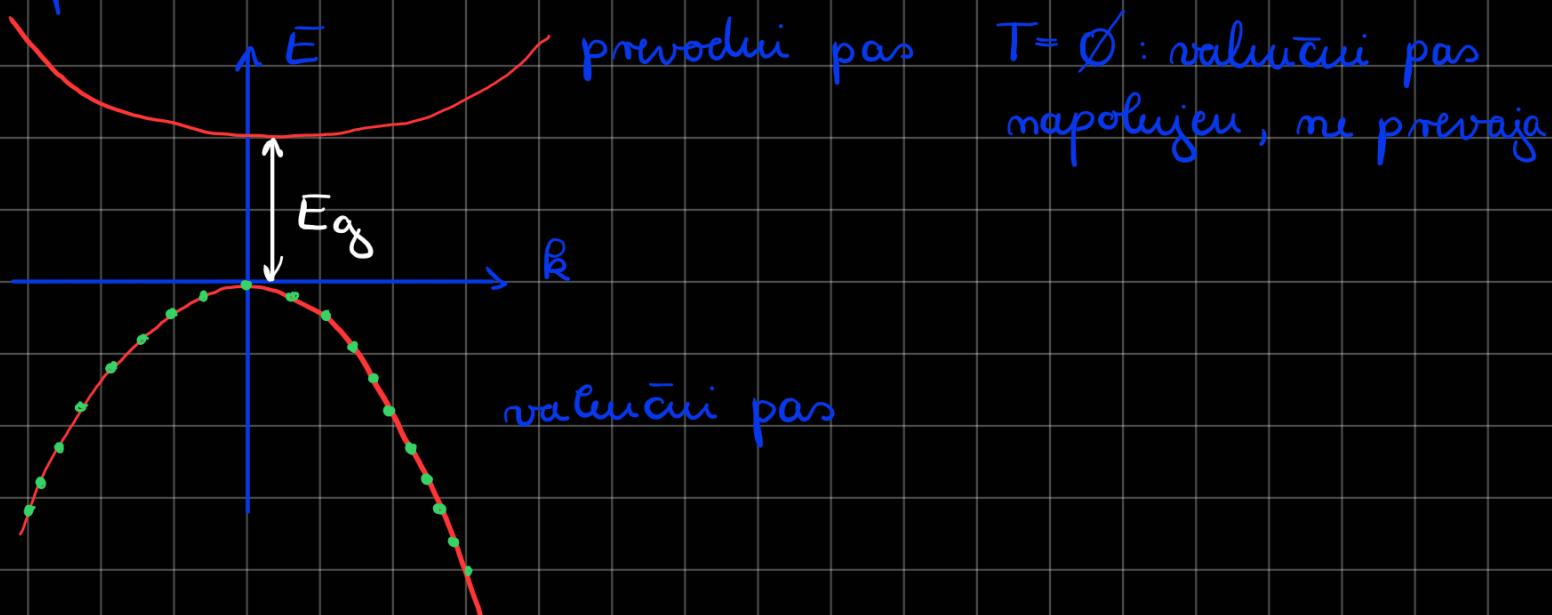


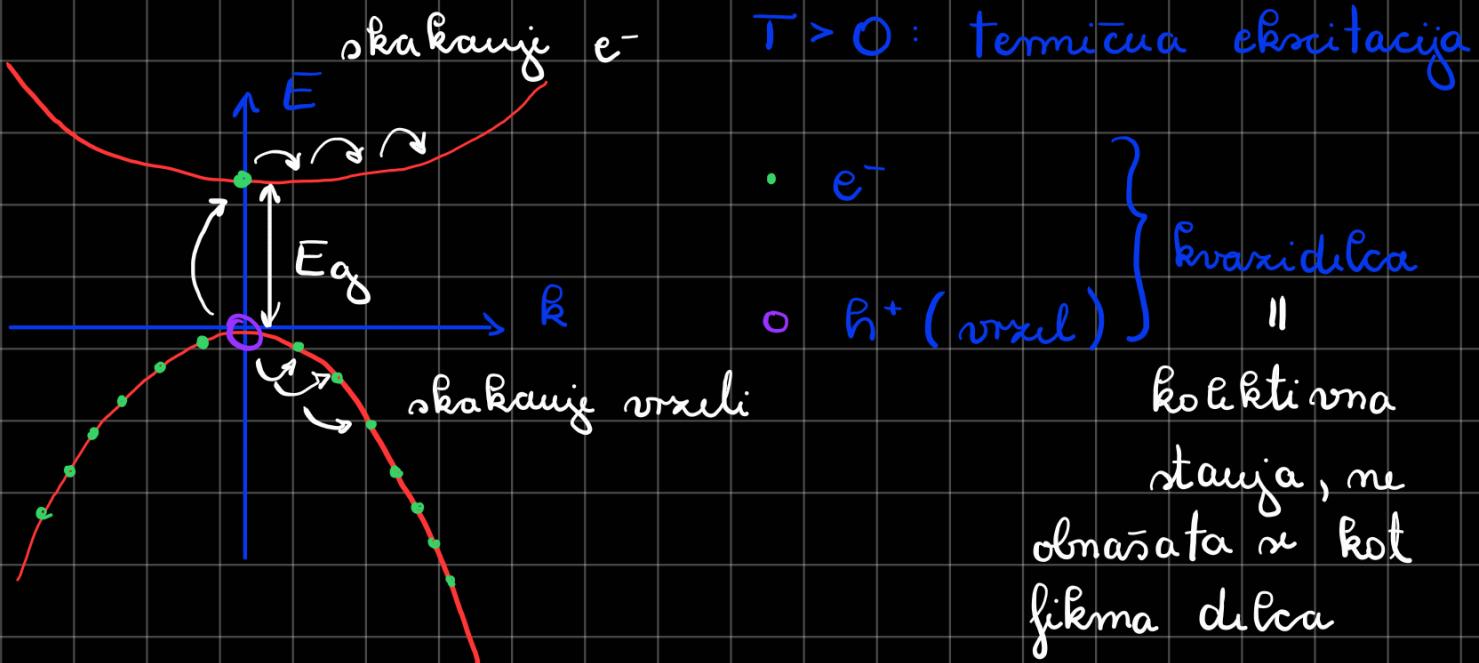
Polprvodeniki

Praksa: omejijo se na 1. Brillouinovo cono, porabijo ma spodnje parove in mapujut v valucni pas do E_F (min. val. pa je $v \neq 0$)



Polprvodeniki





K prevodnosti prispeva skakanje e^- iz enega stanja v drugo in prav tako skakanje vrvili.

$$\text{Prasti } e^-: E = \frac{\hbar^2 k^2}{2m}$$

$$\text{Vrvil/}e^- \propto \text{prevodnik/valučnik paru}: E = \frac{\hbar^2 k^2}{2m^*}$$

m^* ... ef. masa je povzeta na ukrivljenoostjo paru $E(k)$

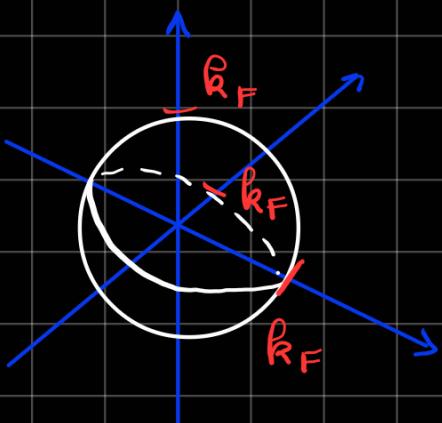
$$\frac{1}{m^*} = \frac{1}{\hbar^2} \frac{\partial^2 E}{\partial k^2}$$

Zauima mas $\frac{dN}{dE} =$ ↗ gostota stanj
 $\qquad\qquad\qquad g(E) f(E)$
 ↗ verjetno stanja porazdelitev
 (Fermi - Diracova)

$$g(E) = \frac{d\alpha}{dE} \rightarrow \alpha \dots \# e^- stanj na en. intervalu$$

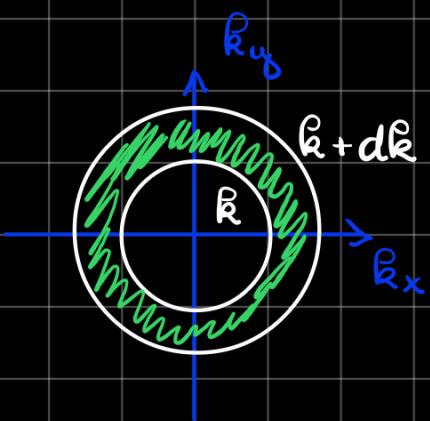
$$\text{alt. xapis} \quad g(E) = \frac{da}{dk} \frac{dk}{dE}$$

v 3D: Fermijeva krogla:



Projekcija v 2D

$$1 \text{ rotanje: } \frac{(2\pi)^3}{L}$$



v 3D enačba $4\pi k^2 dk$

$$da = 2 \frac{4\pi k^2 dk}{(2\pi)^3 / L}$$

↳ degeneracija

$$E = \frac{\frac{h^2 k^2}{2m^*}}{2m^*} \Rightarrow k^2 = \frac{E 2m^*}{h^2}$$

$$\frac{dE}{dk} = \frac{2h^2 k}{2m^*} = \frac{h^2 k}{m^*} \Rightarrow dk = \frac{m^*}{h^2 k} dE$$

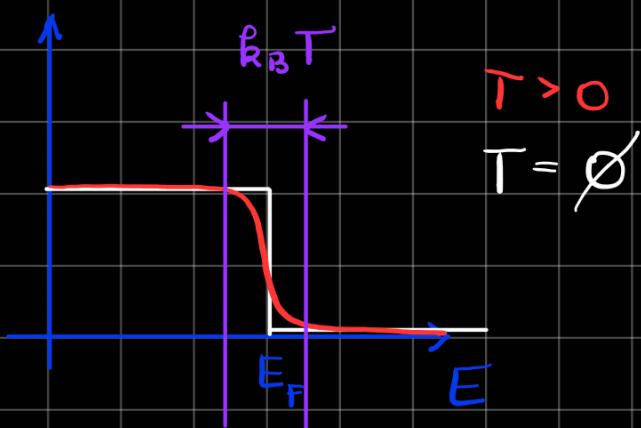
$$g(E) = \frac{4\pi (2m^*)^{\frac{3}{2}}}{h^3} \sqrt{E}$$

// Na kolo kviju lahko, da monas sami izpeljati mpr.
za 2D (izpelji!)

$$f(E) = \frac{1}{e^{\beta(E-\mu)} + 1}, \quad \mu \dots \text{kemijski potencial}$$

$$\mu(T=0) = E_F$$

// za cisto mon



Za pravodruški e⁻ je g(E)

$$\mu \sim E_F \Rightarrow \text{blizu } \frac{E_F}{2}$$

$$\frac{1}{\beta} = \frac{1}{40} \text{ eV} \ll E - \mu \approx 1 \text{ eV}$$

Približek $\delta(E) = e^{-\beta(E-\mu)} e^{-\beta(E-E_g)}$ // Taylor

$$n_{el} = \frac{N_d}{V} = \frac{1}{V} \int_{E_g}^{\infty} g(E) \delta(E) dE$$

// prevodniški pas

$$= e^{-\beta(E_g - \mu)} \frac{4\pi (2m^*)^{\frac{3}{2}}}{h^3} (k_B T)^{\frac{3}{2}} \int_0^{\infty} u^{\frac{1}{2}} e^{-u} du$$

$$u = \frac{E - E_g}{k_B T} \quad \Gamma\left(\frac{3}{2}\right)$$

$$= n_{o,e} \exp\left\{-\beta(E_g - \mu)\right\},$$

$$n_{o,e} = 2 \left(\frac{2\pi m_e^* k_B T}{h^2} \right)^{\frac{3}{2}}$$

Vzeli v valuum pasu (enota obmjeva)

$$E \rightarrow -E$$

$$\Rightarrow g(E) = \frac{4\pi (2m^*)^{\frac{3}{2}}}{h^3} \sqrt{-E} \quad // \text{ni problematično, saj integriramo po intervalu } (-\infty, 0)$$

$$\delta_v(E) = 1 - \delta(E) = 1 - \frac{1}{e^{\beta(E-\mu)} + 1} = e^{\beta(E-\mu)}$$

$$n_{el} = \frac{N_{el}}{V} = \frac{1}{V} \int_{-\infty}^0 g(E) \delta(E) dE = \\ = n_{e,v} e^{-\beta \mu}, \quad n_{e,v} = \left(\frac{2\pi m_v^* k_B T}{h^2} \right)^{\frac{3}{2}}$$

// m^* je abs. vrednost ef. mase

Prodot m_e x m_v je modviseu od μ_0

$$m_e \cdot m_v = n_o^2(T) e^{-\beta E_g}$$

$$n_o(T) = \left(\frac{2\pi \sqrt{m_e^* m_v^*} k_B T}{h^2} \right)^{\frac{3}{2}}$$

Cisti polprivednik

$$m_e = m_v \quad (\text{to upostevamo})$$

$$n_{o,e} \exp \left\{ -\beta (E_g - \mu) \right\} = n_{e,v} e^{-\beta \mu}$$

$$\left(\frac{m_{el}^*}{m_v^*} \right)^{\frac{3}{2}} = e^{-\beta (2\mu - E_g)}$$

$$\mu(T) = \frac{1}{2} E_g + \frac{3}{4} k_B T \ln \frac{m_{el}^*}{m_v^*}$$

5/29

$$T_0 = 20^\circ\text{C}$$

$$\frac{\Delta R}{R} = 0.001$$

$$E_\alpha = 0.72 \text{ eV}$$

Kako natačnus lažko meriuo T?

$$R = \zeta \frac{1}{s\ell}$$

$$\zeta = \frac{1}{\gamma}$$

Prirodniost: $\dot{\gamma} = \gamma E$ (lič. održiv na E) (1)

$$\dot{\gamma} = m_e e_0 \langle v \rangle = \underbrace{m_{el} e_0 \langle v \rangle}_{\text{el.}} + \underbrace{m_v e_0 \langle v \rangle}_{\text{vrzuli}} \quad (2)$$

2 prispevka k prirodniosti

$$\gamma = \frac{m_0 e_0^2 \tau}{m}$$

$$\Rightarrow \dot{\gamma} = (\beta_{el} + \beta_v) E = \left(\frac{m_v e_0^2 \tau_v}{m_v} + \frac{m_{el} e_0^2 \tau_{el}}{m_{el}} \right)$$

$$m_{el} = m_v = m_0(T) e^{-\beta \frac{E_\alpha}{2}}$$

Imaušo $\delta = \frac{\dot{\delta}}{\omega}(\tau)$ sudaj želimo spraviti v drug. obliko
 $(\ln R \rightarrow \ln(\delta)/\frac{d}{\omega})$

$$\ln(R) = \ln(l) - \ln(\beta) - \ln(s) \quad / \frac{d}{d}$$

$$\frac{dR}{R} = \cancel{\frac{dl}{l}} - \frac{d\beta}{\beta} - \cancel{\frac{ds}{s}}, \quad l \neq l(\tau), s \neq s(\tau)$$

$$\left| \frac{dR}{R} \right| = \left| \frac{d\beta}{\beta} \right|$$

$$\beta = e^{-\frac{E_\alpha}{k_B T}} \left(\frac{\gamma_v}{m_v^*} + \frac{\gamma_e}{m_e^*} \right) m_o(T) e^{-\beta \frac{E_\alpha}{2}}$$

$m^* \neq m^*(T)$

predpostavimo $\gamma \neq \gamma(T)$ (druogā į)

$$\frac{d\beta}{\beta} = \frac{dm_o(T)}{m_o(T)} - d\left(\beta \frac{E_\alpha}{2}\right)$$

\checkmark želimo $\frac{d\beta}{\beta} = \frac{d\beta}{\beta} \left(\frac{dT}{T} \right)$

$$\frac{dm_o(T)}{m_o(T)} - \frac{1}{m_o} dT = \frac{1}{C T^{\frac{3}{2}}} \cancel{C^{\frac{3}{2}} T^{-\frac{1}{2}}} dT \frac{1}{T} = \frac{3}{2} \frac{dT}{T}$$

velja $m_o(T) = C T^{\frac{3}{2}}$

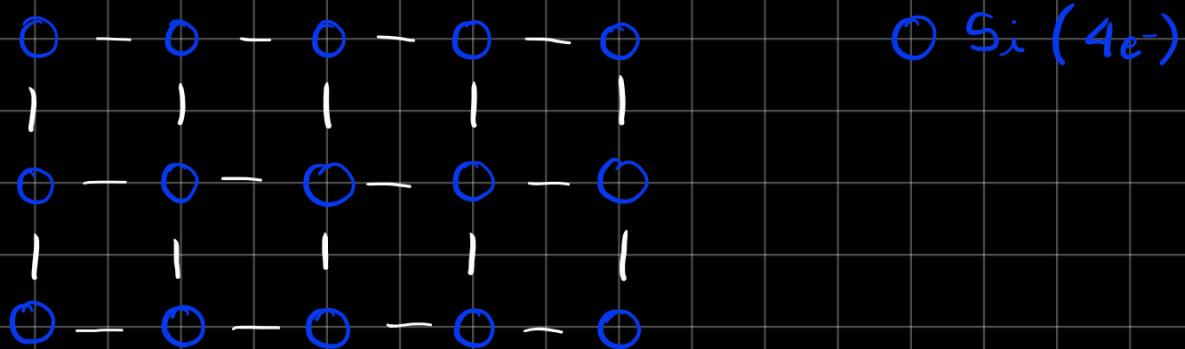
$$\Rightarrow \frac{E_\alpha}{2} \frac{1}{k_B T} \Rightarrow \frac{E_\alpha}{2} \frac{1}{k_B T^2} dT$$

$$\frac{d\beta}{\beta} = \frac{dm_o(T)}{m_o(T)} - d\left(\beta \frac{E_\alpha}{2}\right) \frac{dT}{dT}$$

$$\frac{d\beta}{\beta} = \frac{dR}{R} = \left(\frac{3}{2} + \frac{E_A}{2R_B T} \right) \frac{dT}{T}$$

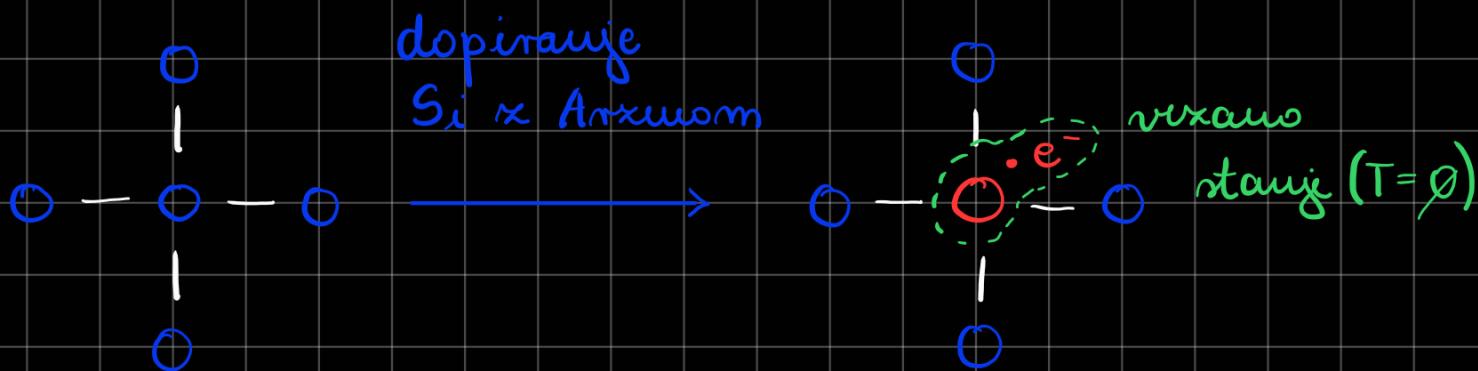
$$\Rightarrow \frac{dT}{T} = \frac{\frac{dR}{R}}{\left(\frac{3}{2} + \frac{E_{\infty}}{2k_B T}\right)}$$

Dopirani polprevodník



1) poliprewodnik tipa m

Rudko dopirau



Ene. disperzija

