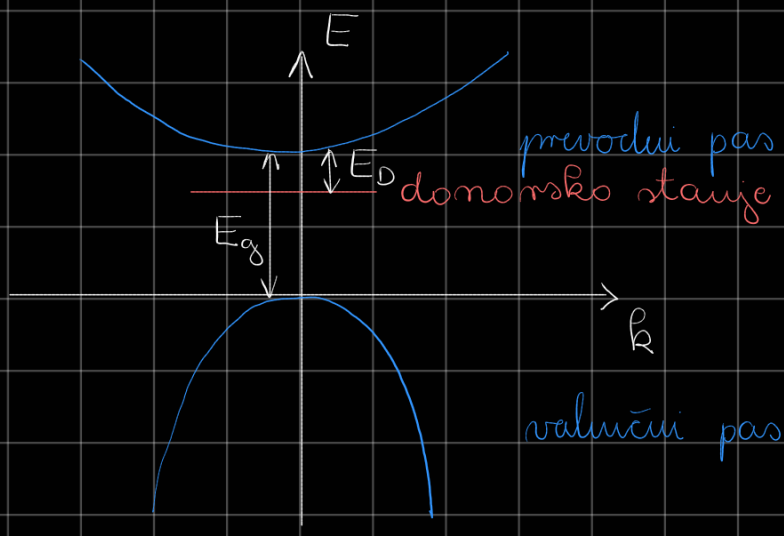
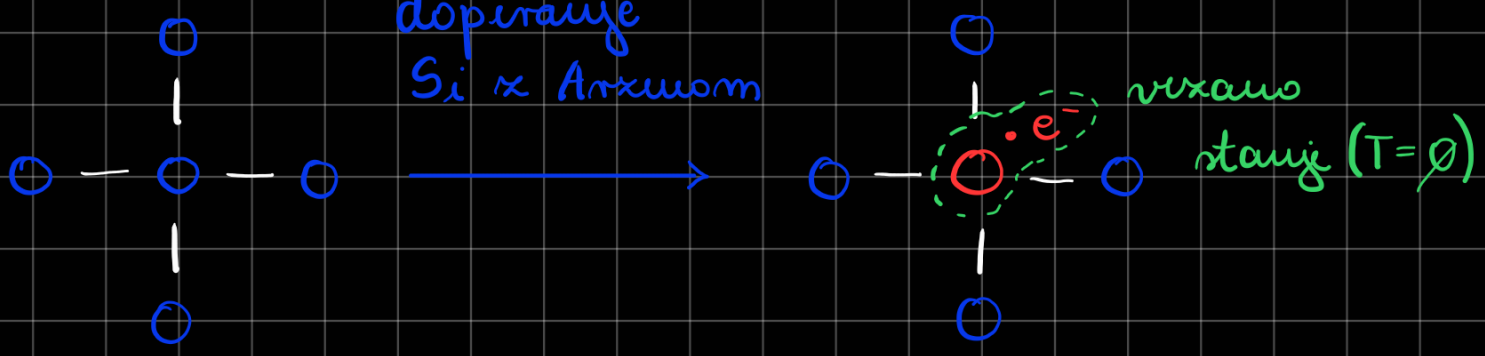
Dopirani polprevodniki

→ tip n (ker prevaja, je negativen, nosilci naboja so e^-)

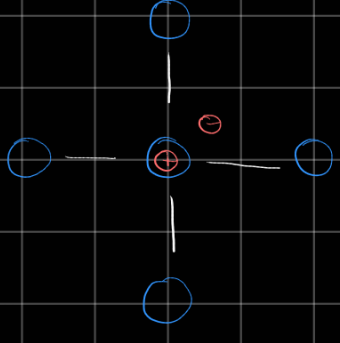


velja $E_g \gg E_D$

O arzen (5e⁻)



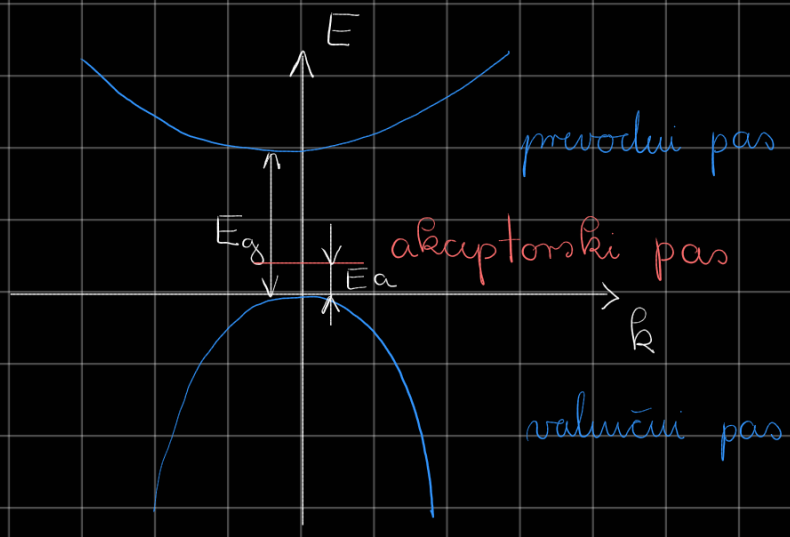
Lahko si mislimo, da namesto Arzena imamo Si, ki mu dodamo en p^+ in en e^-



Pri T=0 je dopiran polprevodnik izolator in prevodni pas

prazen.
Z majhnim dvigom T začnemo prevajati zaradi preskoka e^- iz donorskega pasu (do visoke temp. bo večino e^- za prevajanje izhajalo iz donorskega pasu, potem pa iz valenčnega)

→ tip p (protoni)



$E_a \ll E_g$

e^- skočijo v akceptorski pas → nastanejo vrzeli, ki potem prevajajo

Fermi-Diracova porazdelitev za dopirane polprevodnike

$$f_D(E) = \frac{1}{\left(\frac{1}{2}\right) e^{+\beta(E_g - E_d - \mu)} + 1}$$

↳ posledica Coulombske interakcije med e^- vezanimi na nečistoči

Izpeljava

———— ε lahko zasedijo 0, 1, 2 elektrone

$\hat{H} = \sum (\hat{n}_i + \hat{n}_j) + U \hat{n}_i \hat{n}_j$ Hamiltonian

$\langle n \rangle =$ ————

iz STD: $\langle n \rangle = \frac{Tr[\hat{H}\hat{n}]}{Tr[\hat{H}]} = \frac{\sum_j n_j e^{-\beta(E_j - \mu n_j)}}{\sum_j e^{-\beta(E_j - \mu n_j)}}$ → povp. št. stanj; } normiramo

Imamo $\emptyset$ e^-:

praznu pas —— $E_0 = \emptyset$

1 e^-:

dve stanji $\uparrow$ $\downarrow$ degenerirana $E_{1\uparrow} = \varepsilon$, $E_{2\downarrow} = \varepsilon$

2 e^-: $\downarrow\uparrow$ $E_2 = 2\varepsilon + U$ → prispevek interakcije

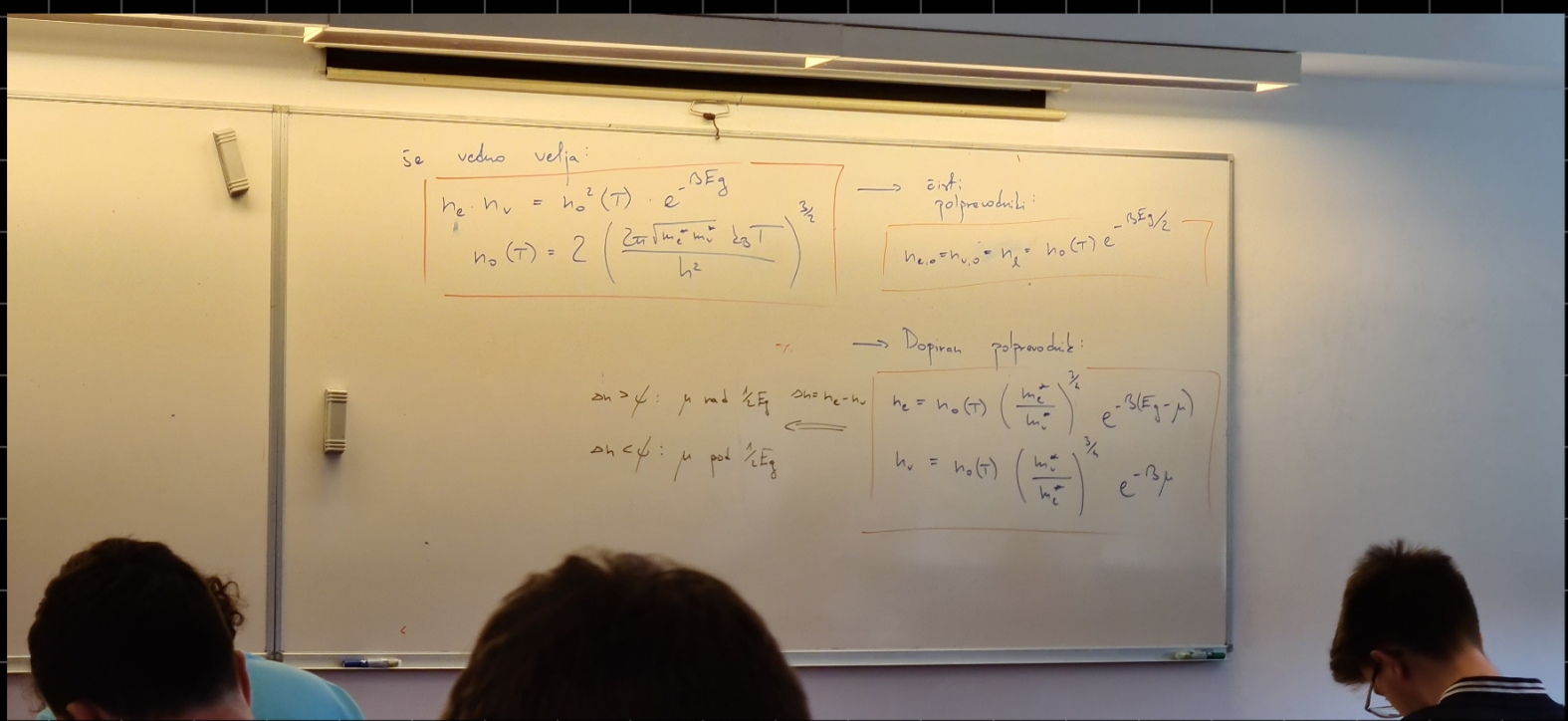
n_j ↑ exp[ ] ↑

$$\langle n \rangle = \frac{\emptyset \cdot 1 + 2 \cdot 1 \cdot e^{-\beta(E-\mu)} + 2 \cdot e^{-\beta(2\varepsilon - U - 2\mu)}}{1 + 2 e^{-\beta(E-\mu)} + e^{-\beta(2\varepsilon - U - 2\mu)}}$$

Velja $\boxed{U > \varepsilon}$ za nečiste če (Coulombska interakcija jo naredi neugodno)

$$\langle n \rangle \approx \frac{1}{\frac{1}{2} e^{\beta(\varepsilon-\mu)} + 1}$$

analogno za akceptorje



Žarko 4.15

$T_0 = 200\,K$

$\rho = 3'6 \cdot 10^9\ \Omega m$

$n_D = 1'1 \cdot 10^{2m}\ /m^3$

$E_D = 0'054\,eV$

$E_g = 1'12\,eV$

$m_e^* = 1'08\, m_0$

$m_v^* = 0'56\, m_0$

$\eta_e = 0'40\ m^2/V_0$

$\eta_v = 0'22\ m^2/V_0$

$\mu = ?$

$\frac{n_{ion}}{n_D}$

$j = \beta E$

$j = ne \langle v \rangle = ne \eta E$, $\beta = ne\eta$

$\beta = n_e \eta_e e_0 + n_v \eta_v e_0$ // e^- v prevodnem pasu / vrzeli

$+ n_v \eta_e e_0 + n_D \left[1 - f_D (E_g - E_d)\right] \eta_e e_0$ (n_{ion})

e^-, ki pridejo iz valenčnega pasu

e^-, ki pridejo iz donorskega pasu

Dokaz, da lahko $n_v \eta_v e_0$ (lastna prevodnost) zanemarimo

Čisti polprevodnik: $n_e = n_0(T)\, e^{-\frac{\beta E_g}{2}} = 7{,}4 \cdot 10^{10}/m^3$

$\beta_l = n_e e_0 (\eta_e + \eta_v) \sim 10^{-9} / \Omega m$

v primerjavi z dano $\beta = 10^4$

$\Rightarrow n_{ion} = \frac{\beta}{\eta_e e_0} \Rightarrow \frac{n_{ion}}{n_D} = 0{,}51$

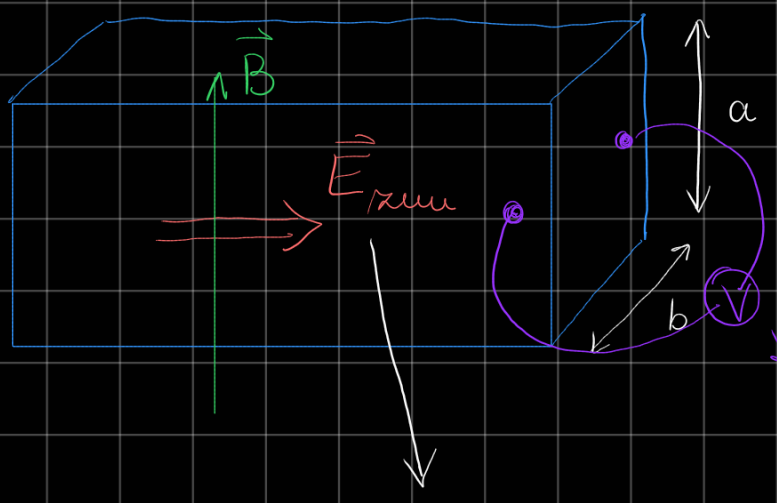
$1 - f_D = 0{,}51$,

$f_D = \frac{1}{\frac{1}{2} e^{\beta(E_g - E_D - \mu)} + 1}$ // izrazi vem μ

$\mu = 1{,}058\ eV$

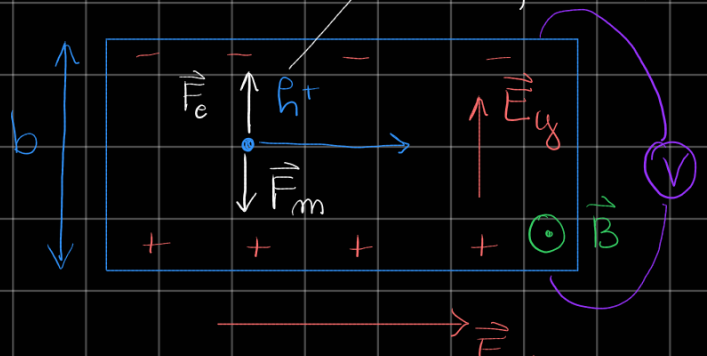
Hallov pojav

Če merimo napetost, lahko določimo št. gostoto nosilcev naboja in njihov predznak naboja



$\vec{B}$ homogeno B polje $\perp \vec{E}_{zunaj}$

tip p: tloris



$\vec{E}_x \gg \vec{E}_y$

tip n: analogno, ampak $h^- \leftarrow$, in $+ \longleftrightarrow -$ se zamenjata

Za stac. stanje, velja mehansko ravnovesje

$$F_e = F_m$$

$$e_0 E_y = e_0 \langle v \rangle B \Rightarrow E_y = \langle v \rangle B \quad , \quad j = n e_0 \langle v \rangle$$

$$E_y = \frac{\jmath B}{ne}, \qquad U_H = E_y b \quad \text{Hallova napetost}$$

$$\jmath = \frac{I}{S} = \frac{I}{ab}$$

$$\Rightarrow \boxed{U_H = \frac{IB}{nea}}$$

Hallov koeficient

$$R_H = \frac{E_y}{\jmath B} = \frac{1}{ne}$$

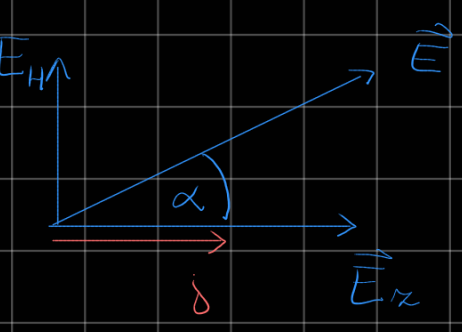
Topič V/50

tip n

$B = 0'3\,T$

$\alpha = 5'7°$

$\zeta = 100\,/\Omega m$



$\downarrow$

smer toka

$n_e = ?$ gibljivost e^-

$n_e = ?$

$$tg\,\alpha = \frac{E_H}{E_x} = \frac{\langle v \rangle B_0}{E_x}$$

Upostevamo $\langle v \rangle = n_e E_x$

$\downarrow$

samo zunanje polje, ki povzroča tok

$$tg\,\alpha = \mu_e B_0$$

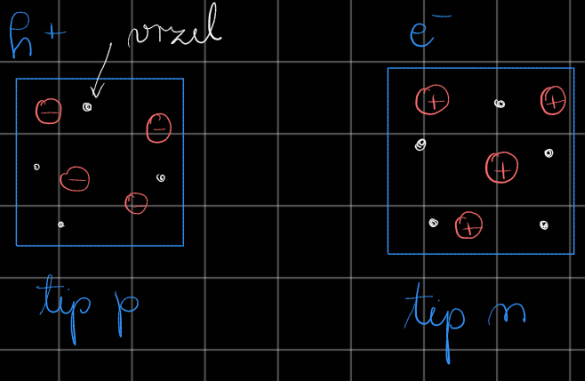
$$\Rightarrow \mu_e = \frac{tg\,\alpha}{B_0} = 0{,}33\ m^2/Vs$$

št. gostota e^-

prevodnost $\beta = \mu_e n_e e \Rightarrow n_e = \frac{\beta}{\mu_e e} = 1{,}9 \cdot 10^{21}/m^3$

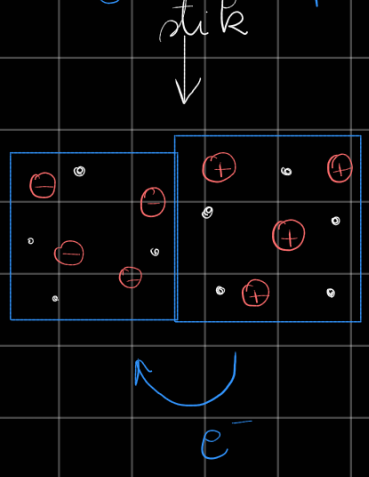
P-N stik (dioda)

Več PN stikov $\Rightarrow$ tranzistor



Risimo samo nečistoče, nakljućni $\pm$ naboj

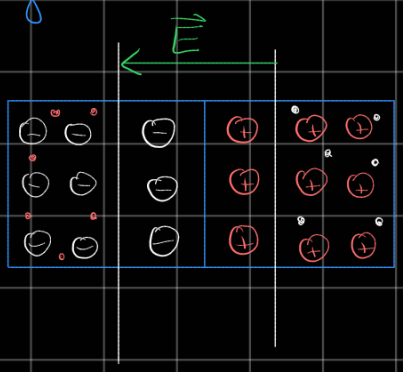
homogeno razpacan naboj, neperiodično



Prehod se zgodi zaradi drugačnih kemijskih potencialov

e^- anihilirajo h^+ vrzeli

Na mují dobrou



záporná část