Kristali

$\alpha_{M,i} = \sum_{j\neq i} \frac{Z_j}{r_j/a}$ (Madelungova konstanta)
$V_{C,i} = \frac{e_0 \alpha_{M,i}}{4\pi\varepsilon_0 a}$
$W_{C,i} = Z_i e_0 V_{C,i}$
$V = \frac{N}{2} V_{C,i} + V_{\text{odb,k}} + \frac{N}{2} W_i - \frac{N}{2} W_a$

Blochov teorem

$\psi = e^{i\mathbf{k}\cdot\mathbf{r}} u(\mathbf{r})$, kjer ima $u(\mathbf{r})$ enako periodo kot $V(\mathbf{r})$, torej $u(\mathbf{r}+\mathbf{r}_0) = u(\mathbf{r}) \implies \psi(\mathbf{r}+\mathbf{r}_0) = e^{i\mathbf{k}\cdot\mathbf{r}_0}\psi(\mathbf{r})$.

Kronig-Penny-ev model kovinske vezi

$V(x) = \begin{cases} 0; & 0 \le x < a \\ V_0; & -b \le x < 0 \end{cases}$ in $V(x+a+b) = V(x)$

$\psi(x) = \begin{cases} Ae^{ikx} + Be^{-ikx}; & 0 \le x < a \\ Ce^{\kappa x} + Be^{-\kappa x}; & -b \le x < 0 \end{cases}$ in $\psi(x+a+b) = \psi(x)$

$k = \sqrt{\frac{2mE}{\hbar^2}} \qquad \kappa = \sqrt{\frac{2m(V_0-E)}{\hbar^2}}$

S približkom $b \to 0, V_0 \to \infty, P = \frac{\kappa^2 ab}{2} = konst.$ dobimo:
$P\frac{\sin(ka)}{ka} + \cos(ka) = \cos(k_l a)$
$k_l = \frac{2\pi l}{Na}, \qquad l = 1, 2, \ldots$

Valenčni pas je najvišji energijski pas v katerem so pri $T \to 0$ energijski nivoji še zasedeni z elektroni.
Prevodni pas je najnižji energijski pas v katerem so pri $T \to 0$ vsi energijski nivoji nezasedeni.
$P(\text{preskok med pasoma}) = \exp\left\{-\frac{E_g}{k_B T}\right\}$

Izolator: valenčni pas popolnoma zapolnjen, prevodni pas prazen. $E_g \sim 10$ eV.
Prevodnik: valenčni in prevodni pas sta enaka.
Polprevodnik: tudi pri nizkih T lahko elektroni preskočijo v prevodni pas. $E_g \sim 1$ eV.

Fermijeva energija

$F_{Fe}(E) = \left(\exp\left\{\frac{E-\mu}{k_B T}\right\} + 1\right)^{-1}$
$\rho_E = \frac{\mathrm{d}g}{\mathrm{d}E} = 4\pi(2m)^{\frac{3}{2}} \frac{V}{h^3}\sqrt{E}$
$N_{Fe} = \int_0^\infty \rho_E F_{Fe}\,\mathrm{d}E \approx \int_0^{E_F} \rho_E\,\mathrm{d}E$
$E_F = \mu(T\to 0) = \frac{h^2}{2m}\left(\frac{3N}{8\pi V}\right)^{\frac{2}{3}} = \frac{mv_F^2}{2}$

Drudejev model prevodnosti

$p(t) = (p_0 - qE\tau)e^{-t/\tau} + eE\tau$
$j = \frac{\mathrm{d}e}{S\mathrm{d}t} = ne_0\langle v\rangle$
$\langle v\rangle = \frac{p(t\to\infty)}{m} = \frac{eE\tau}{m} = \beta E$
$\sigma_0 = \frac{j}{E} = \frac{ne_0^2\tau}{m}$
$\tau = \frac{a}{\langle v\rangle} \approx a\sqrt{\frac{m}{3k_B T}}$
Izmenični tok: $\sigma = \frac{\sigma_0}{\sqrt{1+\omega^2\tau^2}} e^{i\arctan(\omega\tau)}$

Efektivna masa

$m^* = \hbar^2 / \frac{\mathrm{d}^2 E}{\mathrm{d}k^2}$
$E = \frac{p^2}{2m^*} = \frac{\hbar^2 k^2}{2m^*}$

Polprevodniki

Definiramo $E = 0$ na vrhu valenčnega pasu.

Elektroni v prevodnem pasu ($E - E_f \gg k_B T$):
$\rho_e \propto \sqrt{E - E_g}$
$F_e = e^{-(E-E_F)/k_B T}$
$n_e = \frac{N_e}{V} = 2\left(\frac{2\pi m^* k_B T}{h^2}\right)^{\frac{3}{2}} e^{-(E_g - E_F)/k_B T}$
$v_e = \beta_e E$

Vrzeli v valenčnem pasu ($E - E_f \gg k_B T$):
$\rho_v \propto \sqrt{-E}$
$F_v = 1 - F_e = e^{-(E_F - E)/k_B T}$
$n_v = \frac{N_v}{V} = 2\left(\frac{2\pi m^* k_B T}{h^2}\right)^{\frac{3}{2}} e^{-E_F/k_B T}$
$v_v = \beta_v E$

$n_e n_v \propto e^{-E_g/kT} \neq f(E_F)$
Čisti polprevodnik: $n_e = n_v \implies E_F = \frac{1}{2}E_g - \frac{3}{4}k_B T \ln\frac{m_e^*}{m_v^*}$

$j = ne_0 v = j_e + j_v = \sigma E$
$\sigma = 2\left(\frac{2\pi m^* k_B T}{h^2}\right)^{\frac{3}{2}} e_0(\beta_e + \beta_v)e^{-E_g/2k_B T}$

Dopirani polprevodniki

Akceptorji imajo en elektron manj kot čisti polprevodnik.
Donorji imajo en elektron več kot čisti polprevodnik.

$n_{e_i} = n_{v_i} \implies n_e - n_D = n_v - n_A$
n-tip: $n_e \approx n_D$
p-tip: $n_v \approx n_A$

p-n stik

$U(x) = \begin{cases} -\frac{e_0 n_D}{2\varepsilon\varepsilon_0}(x - x_n)^2 + U_0; & 0 \le x \le x_n \\ \frac{e_0 n_A}{2\varepsilon\varepsilon_0}(x + x_p)^2; & -x_p \le x \le 0 \end{cases}$
$U_0 = \frac{e_0}{2\varepsilon\varepsilon_0}(n_D x_n^2 + n_A x_p^2)$
$x_n = \left[\frac{2\varepsilon\varepsilon_0 U_0}{e_0 n_D\left(1+\frac{n_D}{n_A}\right)}\right]^{1/2}, \qquad x_p = \left[\frac{2\varepsilon\varepsilon_0 U_0}{e_0 n_A\left(1+\frac{n_A}{n_D}\right)}\right]^{1/2}$
$d = x_n + x_p = \left[\frac{2\varepsilon\varepsilon_0 U_0}{e_0}\frac{n_A + n_D}{n_A n_D}\right]^{1/2}$ (depletirana plast)
$U_0 = \frac{k_B T}{e_0}\ln\frac{n_e n_v}{n_{e_i} n_{v_i}}$ (kontaktna napetost)
$d \propto \sqrt{U_b + U_0} \approx \sqrt{U_b}$
$I = I_0\left(e^{e_0 U/k_b T} - 1\right)$

$C = \frac{\mathrm{d}e}{\mathrm{d}U} = S\sqrt{\frac{\varepsilon\varepsilon_0 n_D e_0}{2(U_0+U_b)}} \quad (n_a \gg n_d \implies d_n \gg d_p)$

Fotodioda

$I = I_0\left(e^{e_0 U/k_b T} - 1\right) - I_f$
$I_f = \eta 2\frac{\mathrm{d}n_f}{\mathrm{d}t} e_0$

Tranzistor

$I_c = \alpha I_e$
$I_b = (1-\alpha)I_e$
$I_b \approx I_0 e^{e_0 U_{be}/k_B T}$
$I_c = \frac{\alpha}{1-\alpha} I_0 e^{e_0 U_{be}/k_B T}$

Jedra

Rutherfordov eksperiment: $\frac{\mathrm{d}N}{\mathrm{d}\Omega} \propto \sin^{-4}\frac{\vartheta}{2}$
$r_j \sin\beta = n\lambda_b$
$r_j = r_0 A^{1/3}$
$\rho_e(r) = \frac{\rho_0}{e^{(r-r_j)/s}+1}$

$M = Zm_p + Nm_n + E_v/c^2$
$E_v = -w_0 A + w_1 A^{2/3} + w_2\frac{Z^2}{A^{1/3}} + w_3\frac{(A-2Z)^2}{A} + w_4\frac{\delta_{ZN}}{A^{3/4}}$
$\delta_{ZN} = \begin{cases} -1; & Z \text{ sod}, N \text{ sod} \\ 0; & \text{en sod en lih} \\ 1; & Z \text{ lih}, N \text{ lih} \end{cases}$

Lupinski model jedra

$\hat{H} = -\frac{\hbar^2}{2\mu}\left(\frac{\partial^2}{\partial r^2} + \frac{2}{r}\frac{\partial}{\partial r} - \frac{l(l+1)}{r^2}\right) + V(r)$
$V(r) = -V_0 / \left[e^{(r-r_j)/s} + 1\right]$ (Saxon-Woodsov potencial)
$\hat{H}_{ls} = -\eta\,\hat{\mathbf{l}}\cdot\hat{\mathbf{s}}$

Nukleona imata $s = \frac{1}{2}$.
Lupine pri Saxon-Woodsu z dovolj veliko η (nl_j):

1. $1s_{1/2} \implies$ magično število 2
2. $1p_{3/2}$, $1p_{1/2} \implies$ magično število 8
3. $1d_{5/2}$, $2s_{1/2}$, $1d_{3/2} \implies$ magično število 20
4. $1f_{7/2} \implies$ magično število 28
5. $2p_{3/2}$, $1f_{5/2}$, $1p_{1/2}$, $1g_{9/2} \implies$ magično število 50
6. $1g_{7/2}$, $2d_{5/2}$, $1d_{3/2}$, $3s_{1/2}$, $1h_{11/2} \implies$ magično število 82
7. $1h_{9/2}$, $2f_{7/2}$, $2f_{5/2}$, $3p_{3/2}$, $3p_{1/2}$, $1i_{13/2} \implies$ mš 126

Spin sodo-lihega (oz. liho-sodega) jedra je enak celotni vrtilni količini zadnjega neparnega nukleona.
Spin sodo-sodega jedra je 0.
Spin liho-lihega jedra ne moremo natančno določiti, možne so vse kombinacije VK zadnjih dveh nukleonov.

Parnost sodo-lihega (oz. liho-sodega) jedra je $(-1)^l$, kjer l pripada zadnjemu neparnemu nukleonu.
Parnost sodo-sodega jedra je $+$.
Parnost liho-lihega jedra je $(-1)^{l_p}(-1)^{l_n}$, kjer l_p, l_n pripadata zadnjima nukleonoma.

Fizikalne konstante

$R = 8\,310\ \frac{\mathrm{J}}{\mathrm{kmol\ K}}$
$N_A = 6{,}02\cdot 10^{26}\ \frac{1}{\mathrm{kmol}}$
$k_B = \frac{R}{N_A} = 1{,}38\cdot 10^{-23}\ \frac{\mathrm{J}}{\mathrm{K}}$

$e_0 = 1{,}602\cdot 10^{-19}$ As
$\varepsilon_0 = 8{,}85\cdot 10^{-12}\ \frac{\mathrm{As}}{\mathrm{Vm}}$
$\mu_0 = 4\pi\cdot 10^{-7}\ \frac{\mathrm{Vs}}{\mathrm{Am}}$
$c_0 = 3{,}0\cdot 10^8\ \frac{\mathrm{m}}{\mathrm{s}}$
$\sigma = 5{,}67\cdot 10^{-8}\ \frac{\mathrm{W}}{\mathrm{m^2K^4}}$
$k_W = 2{,}90\cdot 10^{-3}\ \mathrm{m\cdot K}$

$u = 1{,}66\cdot 10^{-27}\ \mathrm{kg} = 931{,}5\ \frac{\mathrm{MeV}}{\mathrm{c^2}}$
$m_e = 9{,}1\cdot 10^{-31}\ \mathrm{kg} = 0{,}511\ \frac{\mathrm{MeV}}{\mathrm{c^2}}$

$m_p = 1{,}673 \cdot 10^{-27}$ kg $= 938{,}3\ \frac{\text{MeV}}{\text{c}^2} = 1{,}00728u$
$m_n = 1{,}675 \cdot 10^{-27}$ kg $= 939{,}6\ \frac{\text{MeV}}{\text{c}^2} = 1{,}00866u$

$h = 6{,}626 \cdot 10^{-34}$ Js
$hc = 1240$ eV nm
$r_B = 5{,}291 \cdot 10^{-2}$ nm
$E_0 = 13{,}6$ eV

$\alpha_{EM} = \frac{e_0^2}{4\pi\varepsilon_0 \hbar c} = \frac{1}{137}$

$b = 100\ \text{fm}^2$
$r_0 \approx 1{,}1$ fm
$w_0 = 15{,}6$ MeV
$w_1 = 17{,}3$ MeV
$w_2 = 0{,}7$ MeV
$w_3 = 23{,}3$ MeV
$w_4 = 33{,}5$ MeV

$$|V_{\text{CKM}}| = \begin{bmatrix} 0{,}97428 & 0{,}2253 & 0{,}00347 \\ 0{,}2252 & 0{,}97345 & 0{,}0410 \\ 0{,}00862 & 0{,}0403 & 0{,}999152 \end{bmatrix}$$