МЕХАНИЗМЫ ЗАРЯДА ПЕРЕНОСИМОЙ СРЕДЫ. *Научно-технический журнал*, *23*(3), 124-128.

10. Юлдашев, Ш. А. (2023, ноябрь). ИССЛЕДОВАНИЕ ЭФФЕКТА АФН В НЕОДНОРОДНЫХ ТОНКИХ ПЛЕНКАХ. На *конференции Ферганского государственного университета* (с. 283-286)..

11. Onarqulov, K., & Yuldashev, S. (2023, November). YORUG'LIK VA MAGNIT TA'SIRLARDAN FOYDALANIB YUQORI ELEKTR MAYDON HOSIL QILISH. In *Fergana state university conference* (pp. 70-70).

12. Онаркулов, К. Э., Юлдашев, А. А., Юлдашев, Ш. А., & қизи Юлдашева, Ш. А. (2023). ПОЛУЧЕНИЕ СИЛЬНОГО ЭЛЕКТРИЧЕСКОГО ПОЛЯ ОТ СОЛНЕЧНОГО ТЕПЛА И ЭФФЕКТОВ МАГНИТНОГО ПОЛЯ.

BLOCH ELECTRONS IN MAGNETIC FIELDS

Mamatova Mahliyo Adhamovna[1], Hoshimova Hulkaroy Djo'rayevna[2].

Senior teacher at the Department of Physics, Fergana State University[1],

teacher, FCVS[2]

Annotation. Blocking electrons in magnetic fields involves understanding how magnetic fields influence the motion and behavior of electrons. This topic is essential in various fields of physics and engineering, including the design of magnetic confinement devices in fusion reactors, the development of advanced electronic components, and space physics.

Keywords: bloch electrons, magnetic fields, Lorentz forces, cyclotron motion, Landau levels, quantum hall effect, band theory, crystal grille, wave function, magnetic boundary, Brillouin zone, electronic mobility, quantum vibrations

The system is spherically symmetric,

$$\widehat{m}^{-1} = \begin{pmatrix} \frac{1}{m^*} & 0 & 0 \\ 0 & \frac{1}{m^*} & 0 \\ 0 & 0 & \frac{1}{m^*} \end{pmatrix}$$

The energy is represented by

$$\mathcal{E}(k) = \mathcal{E}(0) + \frac{\hbar k^2}{2m^*}. \quad (1)$$

m^* is called the effffective mass. When $\widehat{m}^{-1}$ is diagonal but anisotropic, we have

$$\mathcal{E}(k) = \mathcal{E}(0) + \frac{\hbar}{2m^*}k_x^2 + \frac{\hbar}{2m^*}k_y^2 + \frac{\hbar}{2m^*}k_z^2 \qquad (2)$$

Next, we consider the case when magnetic fifields are present. By the analogy from the free electron case where the substitution , $p \rightarrow p + eA$ is made, with a substitution

$$\hbar k \rightarrow p + eA \qquad (3)$$

for a given energy dispersion *En*(***k***), we obtain the following Schrodinger equation.

$$\mathcal{E}_n\left(\frac{1}{i}\nabla + \frac{e}{\hbar}A\right)\ f(k) = \ \mathcal{E}f(r)$$

If $\mathcal{E}$ has a parabolic form,

$$\mathcal{E}(k) = \mathcal{E}(0) + \frac{\hbar k^2}{2m^*}.$$

$$\frac{1}{2m^*}\left(\frac{1}{i}\nabla + \frac{e}{\hbar}A\right)^2\ f(k) = \ \mathcal{E}f(r)$$

It is known that such a substitution is appropriate in most cases. The substitution is called the Landau-Peierls substitution.

The validity of the Landau-Peierls substitution is shown by Luttinger and Kohn as the effective mass theory [7]. In the effective mass theory, the wave function φ is expanded as a series of the functions

$$\phi_{nk}(r) = \sqrt{\frac{\Omega}{V}u_{n0}(r)e^{ik*r}}$$

which form an orthonormal set,

$$\varphi = \sum_{n'} \int dk' A_{n'}(k')\,\phi_{n'k'}.$$

The function ϕ_{nk} has an orthogonal property

$(\phi_{nk}, \phi_{n'k'}) = \delta(k' - k)\delta_{nn'}.$

The Hamiltonian in the presence of the magnetic field is

$$H = \frac{1}{2m}(p + eA)^2 + U(r), \qquad (4)$$

and

$$H\varphi = \mathcal{E}\varphi$$

is an equation to be solved. Interband interaction terms $<\phi_{n'k'}|H|\phi_{nk}>$ can be taken into the effective mass, and it can be shown that the wave function can have a form

$$\varphi(r) = \sum_n F_n(r)\phi_{n0}(r) \quad (5)$$

Here, the function F_n (***r***) is an eigenfunction of the following Schrodinger equation

for the *n*-th band:

$$\mathcal{E}_n\left(\frac{1}{i}\nabla + \frac{e}{\hbar}A\right)F_n(r) = \mathcal{E}F_n(r) \quad (6)$$

$$\mathcal{E} = \frac{\hbar^2 k^2}{2m^*},$$

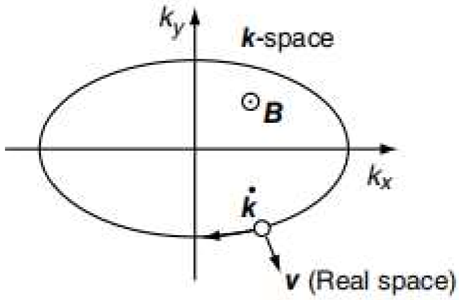
then

$$\varphi(r) = f(r) \times u_n(r). \quad (7)$$

In the Landau gauge, *f*(***r***) is an eigenfunction of the same expression as with $m \rightarrow m^*$, so that it is a harmonic oscillator function. The energy is given

$$\mathcal{E} = (N + \frac{1}{2})\,\hbar\omega_c, \qquad \omega_c = \frac{eB}{m^*} \quad (8)$$

Thus we see that the Landau levels in the conduction band, which has a parabolic energy dispersion, have the same energy as free electrons except that the free electron mass is replaced by the effective mass. The wave function is a product of the slowly varying envelope function standing for the cyclotron motion and the rapidly oscillating Bloch part standing for the periodic motion in the crystal. If the energy band is not entirely parabolic, or if a few bands are degenerate, the solutions are more complicated, but we can obtain the Landau levels by properly treating the dispersion or the degeneracy, as shown in later sections. The essential point of the effective mass approximation is that the effect of the periodic potential of the crystal lattice is squeezed into the effective mass, treating the Schrodinger equation without the periodic potential. It should be



noted that the effective mass approximation is valid not only for the electronic states in the presence of magnetic fields, but also for those in the presence of electric potential. Therefore, it can be applicable for treating impurity states, or electronic states in the presence of artificially introduced quantum potentials in heterostructures, as long as the extension of the envelope wave function is sufficiently larger than the period of the lattice potential.

LITERATURE

1.Solid State Physics" by Neil W. Ashcroft and N. David Mermin
2."Quantum Hall Effect in a Magnetic Field: Analysis of Bloch Electrons" by Haldane, F. D. M. (Physical Review Letters, 1988)
3. Mamatova, M. A., Yavkachovich, R. R., Dilshodbek, M., & Forrukh, K. (2022). Relation between the concentration of nonequilibrium electrons and holes in long semiconductor diodes. *European science review*, (5-6), 29-32.
4. Расулов, В. Р., Расулов, Р. Я., Маматова, М. А., & Исомаддинова, У. М. (2022). К ТЕОРИИ ЭЛЕКТРОННЫХ СОСТОЯНИЙ В МНОГОСЛОЙНОЙ ПОЛУПРОВОДНИКОВОЙ СТРУКТУРЕ. КВАЗИКЛАССИЧЕСКОЕ ПРИБЛИЖЕНИЕ. *Universum: технические науки*, (10-5 (103)), 24-31.
5. Rustamovich, R. V., Yavkachovich, R. R., Adhamovna, M. M., Qizi, K. M. N., & Dovlatboyevich, M. D. (2022). VOLT-AMPERE CHARACTERISTICS OF A THREE-LAYER SEMICONDUCTOR DIODE OF DOUBLE INJECTION. *European science review*, (5-6), 37-41.
6. Rasulov, V. R., Rasulov, R. Y., Mamatova, M. A., & Eshboltaev, I. M. (2022). THEORETICAL INVESTIGATION OF ENERGY STATES IN A MULTILAYER SEMICONDUCTOR STRUCTURE IN THE QUASICLASSICAL APPROXIMATION. *Galaxy International Interdisciplinary Research Journal*, *10*(12), 96-104.
7. Rasulov, V. R., Rasulov, R. Y., Mamatova, M. A., & Qosimov, F. (2022, December). Semiclassical theory of electronic states in multilayer semiconductors. Part 1. In *Journal of Physics: Conference Series* (Vol. 2388, No. 1, p. 012156). IOP Publishing.
8. Маматова, М. А., Исомаддинова, У. М., Кодиров, Н. У. О., & Обидова, М. И. (2022, December). КВАЗИСТАЦИОНАРНЫЕ ЭНЕРГЕТИЧЕСКИЕ СОСТОЯНИЯ В СФЕРИЧЕСКОЙ ПОЛУПРОВОДНИКОВОЙ ПОТЕНЦИАЛЬНОЙ ЯМЕ. In *The 12 th International scientific and practical conference "Eurasian scientific discussions"(December 18-20, 2022) Barca Academy Publishing, Barcelona, Spain. 2022. 542 p.* (p. 226).