**Excitations in B field w/ disorder**

Gonna keep going, but generalizing a bit, without too much justification 😊.

**Generalizing to particle in B field and realistic 1D electric potential**

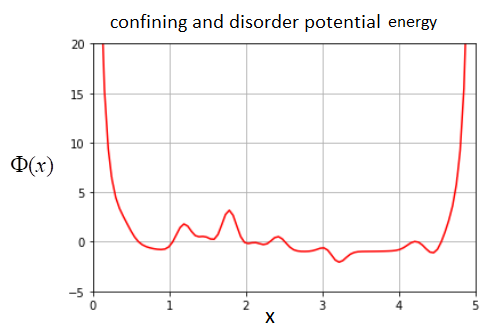
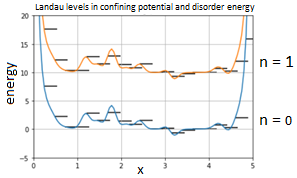
So let’s extrapolate to a more realistic 1D potential energy Φ(x), would include a confining potential, and disorder, which would make the electric potential energy concave up near the edges, but rather chaotically disordered within the bulk.



[e carries sign] Then using the WKB approximation, we should find that we get approximate energy levels like this:



where xc locates the center of the wavefunction, and is functionally related to ky, though precisely how is unknown. And we interpret the three terms in the energy as quantum kinetic energy due to fuzziness of position of particle and its diamagnetic orbital motion about the magnetic field lines, its drift kinetic energy in the direction of E×B, and its classical electrostatic potential energy. So the Landau levels will now mimic the function form of Φ(x), as illustrated below:

For a weak enough potential/strong enough B, the electric field shouldn’t mix Landau levels, and they should be still separated. So we can still speak of the number of states within a Landau level. Remember ky is required to be periodic and so this discretizes the allowed xc values, and then the number of states in each Landau level is obtained by imposing condition that xc must remain inside the sample). Under these conditions we should still get the usual result, since slowly turning on an electric field shouldn’t change the number (degeneracy) of states we have:



Yeah the states aren’t technically degenerate since they don’t have the same energy but you know. Apropos that drift velocity, generalizing from our 1D results in previous file, it will be given by:



where E(x) = -∇φ(x) is the electric field at the point x, corresponding to the center of the wavefunction with canonical momentum value ky, or even more generally,



so that it is moving perpendicular to the electric field lines, which would be equivalent to along the equipotentials (it kind of must do this if its energy is to be constant anyway, and its energy must be constant to be a stationary state).

**Generalizing to particle in B field and realistic 2D electric potential**

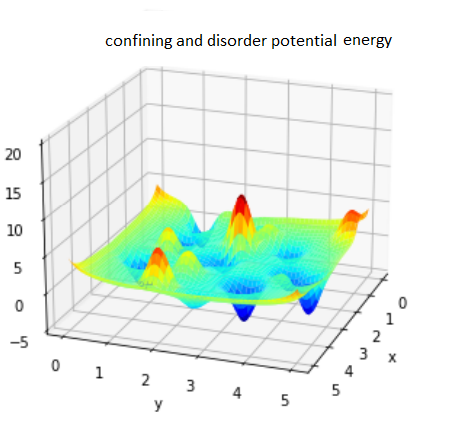
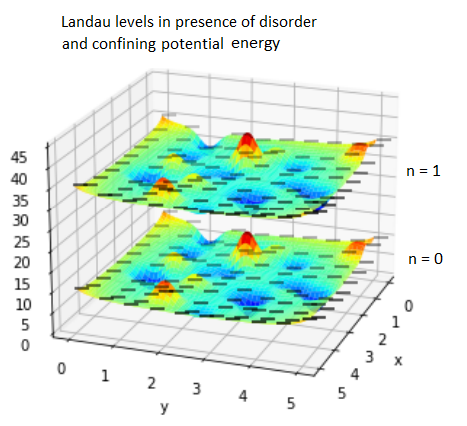
Now let’s generalize to a realistic 2D electric potential which will carry disorder and the confining potential.



[e carries sign] Then using the WKB approximation, like we did in previous file, we should find that we get approximate energy levels like this:



where rc is the position of the peak of the wavefunction, and is scattered throughout the surface of our substance. Again, the first term in the energy is associated with quantum fuzziness radial kinetic energy and diamagnetic orbital kinetic energy + drift velocity kinetic energy + electric potential energy. I plotted a picture of such a random disorder and confining potential to left (disorder probably exaggerated a bit and the confining potential energy would in reality go to ∞, or at least a lot, on the edges, as it did in the 1D graph above, but that’s not rendering very well), and the associated Landau levels (well two of them) to the right.

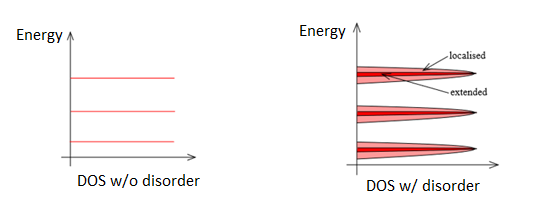
Even though our potential now varies in 2D, adiabatically, we should have that the number of states (ignoring spin d.o.f.) within a single Landau level would still be as it was:



if the potential is fairly weak in comparison to B so that Landau levels don’t cross. And the velocity of a given state would be:



We’ll note again that this velocity is perpendicular to the electric field, and therefore each particle traverses an equipotential. Because of this, it turns out that in 2D, some (most) of the electrons are localized. Can see above that equipotential contour lines at low potentials (blue) and high potentials (red) are isolated, but those at medium levels (green especially, and aqua) extend from one side of the sample to the other. The electrons that would happen to be on the high or low potential contours would therefore be localized, while those on the middle potentials would be extended. We could illustrate this state of affairs in the density of states,



As can kind of see above in the contour map, most of the completely delocalized states (green mainly) will reside along the edge of the Landau level. This means that it is the confining potential which will predominantly control their velocities. The confining potential *energy* will be concave up regardless, and so the confining potential will be concave up if the charges are positive, and concave down if they’re negative. And recalling that:



this would mean that the charges in the delocalized states will predominantly perambulate the sample (as observed looking down from the z-direction) counter-clockwise if positive, and clockwise if negative. Such states, confined to move in 1 direction (at a given location), are called ‘***chiral*** ***states’***. These edge states are hard to scatter he says, because to make an upward moving state go down, the electron would have to scatter from the right side of the sample to the left.

**Some Questions**

* Is the presence of delocalized state/s predicated on large enough B?
* How does this reconcile with statement that all 2D states are supposed to be localized in absence of B?
* How does fact that ξ can often be super large for 2D systems?