Solid State Physics
Lecture 57
Quantum Theory of Diamagnetism

Hello. After discussing the classical theory of diamagnetism, we will discuss the Quantum Theory of Diamagnetism. (Refer Slide Time: 00:34)

And we will do that for mononuclear systems; that means there is one nucleus in the in one unit cell. So, the effect of magnetic field will add some terms in the Hamiltonian, let us write down those terms. So, I am not writing the full Hamiltonian, I am just writing the terms that are added to the Hamiltonian as a result of the application of an external magnetic field, that is given as $H = \frac{ie\hbar}{2mc}(\overrightarrow{\bigtriangledown} \cdot \overrightarrow{A} + \overrightarrow{A} \cdot \overrightarrow{\bigtriangledown}) + \frac{e^2}{2mc^2}A^2$. Now, if we consider an atomic electron, these terms may usually be treated as small perturbations; these are much smaller than the other terms of the Hamiltonian. And if the magnetic field is uniform and it points along the z-direction Then we can express the vector potential in the following way A_x, that is x component of the vector potential would be $A_x = \frac{1}{2}yB$, B is the magnetic field pointing along the z direction, $A_y = \frac{1}{2}xB$ and $A_z = 0$. And with this the Hamiltonian that we wrote earlier can be expressed as $H = \frac{ie\hbar B}{2mc}(x\frac{d}{dy} - \frac{d}{dx}) + \frac{e^2B^2}{8mc^2}(x^2 + y^2)$. Now, the first term here that is this term is proportional to the orbital angular momentum component l_2, if r is measured from the nucleus. In mononuclear system, this term will give rise only to paramagnetism and the second term this one here that, gives for spherically symmetric system a contribution in energy $E' = \frac{e^2B^2}{12mc^2}\langle r^2 \rangle$ expectation value; this is obtained by first order perturbation theory from the second term here. And the associated magnetic moment is diamagnetic for this second term, where $\mu = \frac{\partial E'}{\partial B} = -\frac{e^2\langle r^2 \rangle}{6mc^2}B$ and this is in agreement with the classical result. So, we have got the magnetic moment that comes from the quantum theory of diamagnetism.