Condensed Matter Physics
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Lecture - 34
Energy Bands in Solids

The free electron theory, which was successful in explaining the physical properties of metallic materials has its serious limitations.

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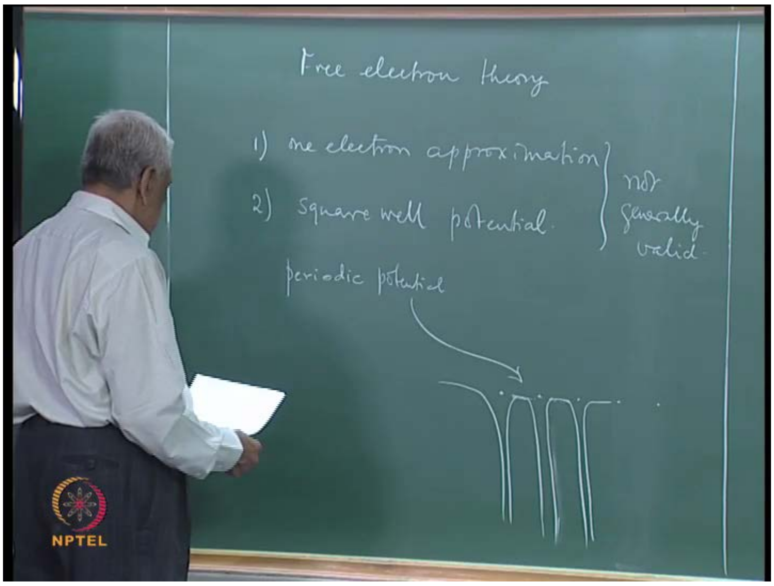

Because it is based on the free electron theory is based on one - one electron approximation, which means that we look at one electron and considered the effect of all the other conductional electrons on it in the form of a square well potential, which is constant throughout the metal. And to which this electron is subject and which prevent it from getting out of the metal as whole. These are the two approximation and they are not generally valid.

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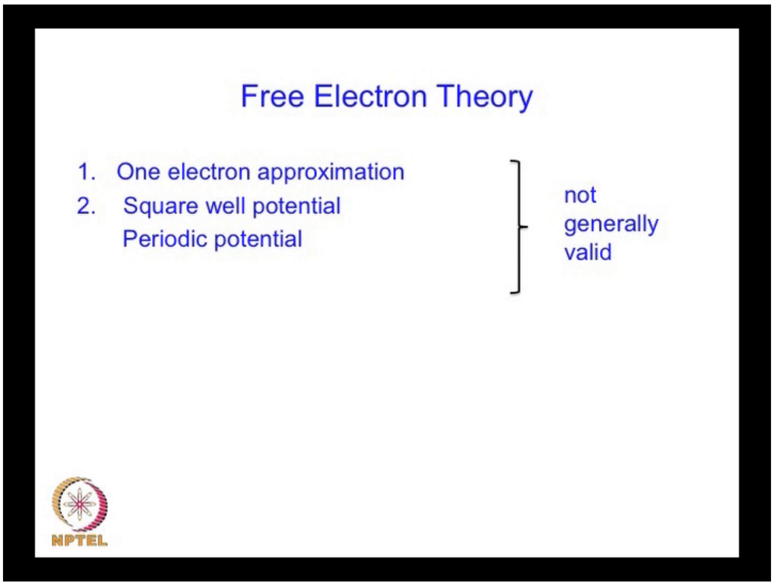

Free Electron Theory

1. One electron approximation
2. Square well potential
   Periodic potential

} not generally valid

So, in order to make further progress, it is necessary to go beyond this approximation mainly consider the more realistic situation in which we consider the periodic potential experienced by an electron due to all the ion cores in the lattice - crystal lattice. So, there are ion cores which are regularly arranged in a crystal lattice in all three dimension, I am showing one-dimensional situation. So, the potential is something like there will be…

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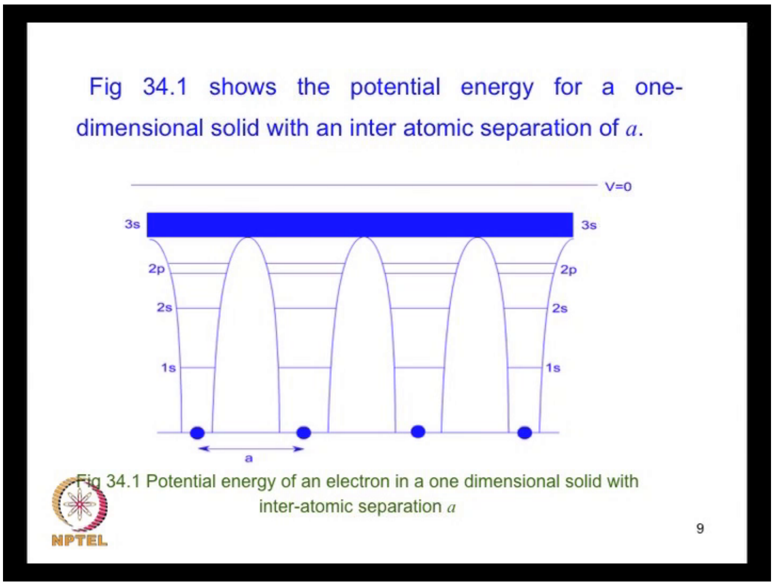

Fig 34.1 shows the potential energy for a one-dimensional solid with an inter atomic separation of a.

Fig 34.1 Potential energy of an electron in a one dimensional solid with inter-atomic separation a

So, and this will repeated self everywhere so and so on. So, this is the periodic potential which we are talking about. This potential has a periodicity of the crystal lattice. So we have to consider the motion of the electron subject to this given by the Schrodinger equation in quantum mechanics.

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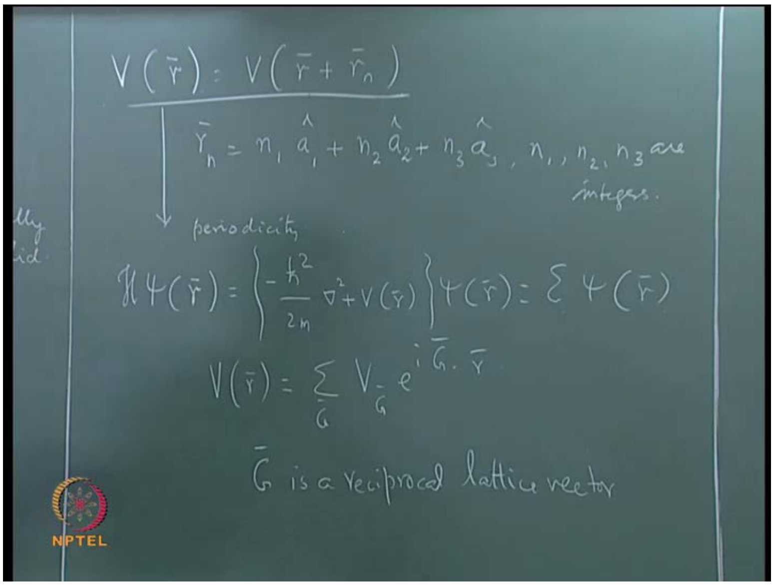

$$V(\bar{r}) = V(\bar{r} + \bar{r}_n)$$

$\bar{r}_n = n_1 \hat{a}_1 + n_2 \hat{a}_2 + n_3 \hat{a}_3$, n_1, n_2, n_3 are integers.

periodicity

$$\mathcal{H}\psi(\bar{r}) = \left\{-\frac{\hbar^2}{2m}\nabla^2 + V(\bar{r})\right\}\psi(\bar{r}) = \varepsilon\,\psi(\bar{r})$$

$$V(\bar{r}) = \sum_{G} V_{\bar{G}}\, e^{i\bar{G}\cdot\bar{r}}$$

$\bar{G}$ is a reciprocal lattice vector

Subject to this periodic potential V of r, which has the periodicity of the crystal lattice. In other words V of r equals where r n is a general lattice vector n 1 a 1 plus n 2 a 2 plus n 3 a 3 and n 1 n 2 n 3 are integers and a 1 a 2 a 3 are the basic translation vectors.

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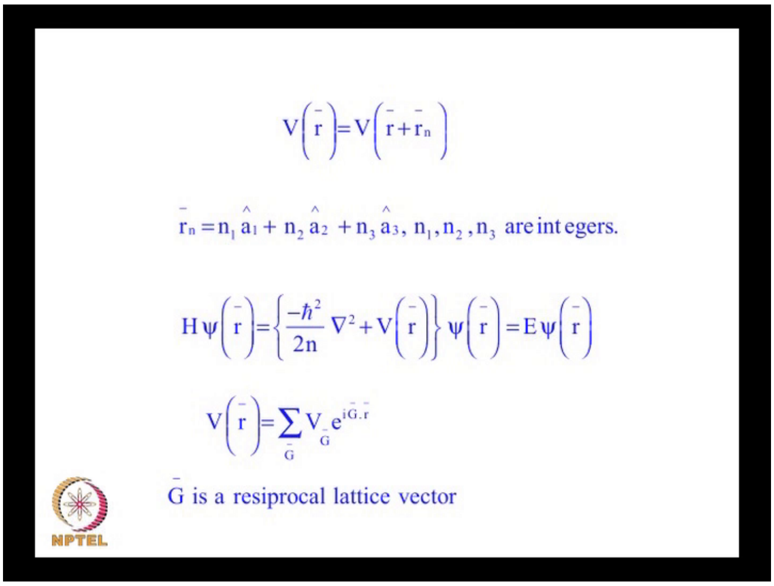

$$V(\bar{r}) = V(\bar{r} + \bar{r}_n)$$

$\bar{r}_n = n_1 \hat{a}_1 + n_2 \hat{a}_2 + n_3 \hat{a}_3$, n_1, n_2, n_3 are integers.

$$H\psi(\bar{r}) = \left\{\frac{-\hbar^2}{2n}\nabla^2 + V(\bar{r})\right\}\psi(\bar{r}) = E\psi(\bar{r})$$

$$V(\bar{r}) = \sum_{\bar{G}} V_{\bar{G}}\, e^{iG.r}$$

$\bar{G}$ is a resiprocal lattice vector

So, this is simply the condition of periodicity that the potential remains same at any given lattice point, and it is equal to the value of potential at any other lattice point given by the position vector r plus r n. So, this is the condition and we have to solve the Schrodinger equation H psi of r equals minus H cross by a by 2 m del square plus V of r psi of r equal to E psi of r. So, we have to find energy Eigen values E by solving this Schrodinger equation subject to this. And because of the periodicity, it is possible to expand this in the Fourier series of the lattice periodic potential in the form where G is a reciprocal lattice vector we already consider this well discussing diffraction of x-rays by a crystal lattice.

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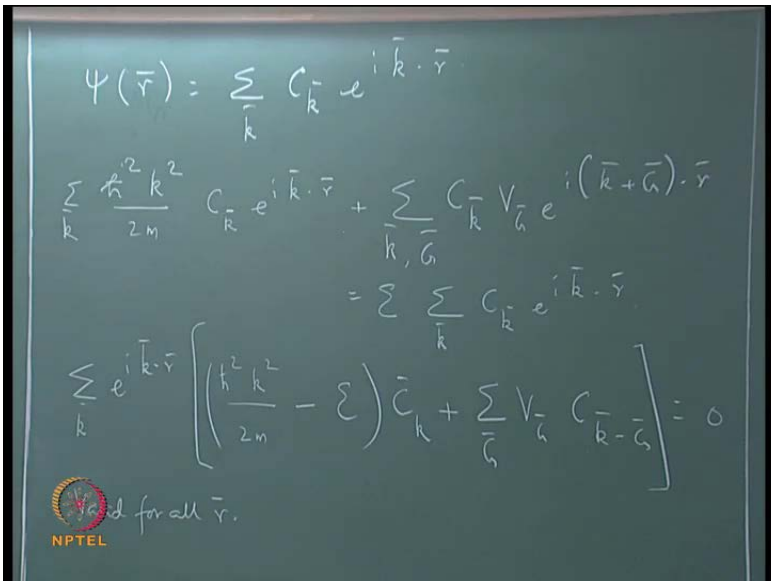

$$\psi(\bar{r}) = \sum_{\bar{k}} C_{\bar{k}}\, e^{i\bar{k}\cdot\bar{r}}$$

$$\sum_{k} \frac{\hbar^2 k^2}{2m} C_{\bar{k}}\, e^{i\bar{k}\cdot\bar{r}} + \sum_{\bar{k},\bar{G}} C_{\bar{k}} V_{\bar{G}}\, e^{i(\bar{k}+\bar{G})\cdot\bar{r}}$$

$$= \mathcal{E} \sum_{\bar{k}} C_{\bar{k}}\, e^{i\bar{k}\cdot\bar{r}}$$

$$\sum_{k} e^{i\bar{k}\cdot\bar{r}} \left[\left(\frac{\hbar^2 k^2}{2m} - \mathcal{E}\right)\bar{C}_k + \sum_{\bar{G}} V_{\bar{G}}\, C_{\bar{k}-\bar{G}}\right] = 0$$

d for all $\bar{r}$.

And we can also expand the plain psi of r in the form of plain waves where k is the wave vector of z electron. So, using this substituting this and this we get equals E sigma k c k a to the power I k dot r.

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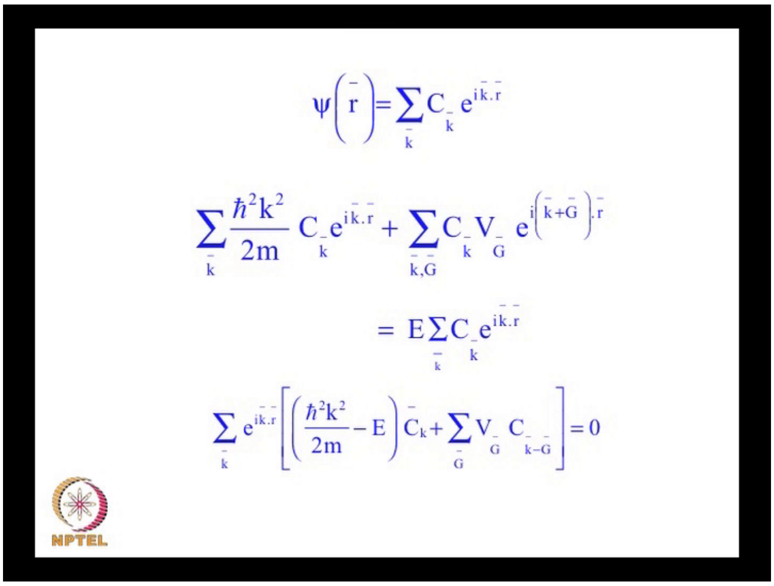

$$\psi(\bar{r}) = \sum_{\bar{k}} C_{\bar{k}} e^{i\bar{k}.\bar{r}}$$

$$\sum_{\bar{k}} \frac{\hbar^2 k^2}{2m} C_{\bar{k}} e^{i\bar{k}.\bar{r}} + \sum_{\bar{k},\bar{G}} C_{\bar{k}} V_{\bar{G}} e^{i(\bar{k}+\bar{G}).\bar{r}}$$

$$= E \sum_{\bar{k}} C_{\bar{k}} e^{i\bar{k}.\bar{r}}$$

$$\sum_{\bar{k}} e^{i\bar{k}.\bar{r}} \left[\left(\frac{\hbar^2 k^2}{2m} - E \right) \bar{C}_k + \sum_{\bar{G}} V_{\bar{G}} C_{\bar{k}-\bar{G}} \right] = 0$$

That will be the equation that we have to solve and this can be written also in the form factoring out a to the power I k dot r we can write this as which is valued for all are which means the square bracket at quantity should vanish.

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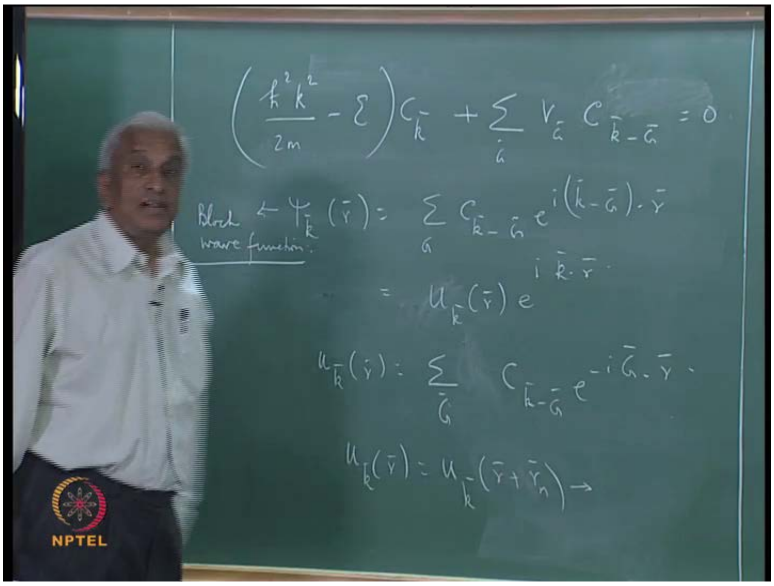

$$\left(\frac{\hbar^2 k^2}{2m} - \mathcal{E} \right) C_{\bar{k}} + \sum_{\bar{G}} V_{\bar{G}} C_{\bar{k}-\bar{G}} = 0$$

Bloch wave function $\leftarrow \psi_{\bar{k}}(\bar{r}) = \sum_{\bar{G}} C_{\bar{k}-\bar{G}} e^{i(\bar{k}-\bar{G}).\bar{r}}$

$$= u_{\bar{k}}(\bar{r}) e^{i\bar{k}.\bar{r}}$$

$$u_{\bar{k}}(\bar{r}) = \sum_{\bar{G}} C_{\bar{k}-\bar{G}} e^{-i\bar{G}.\bar{r}}$$

$$u_{\bar{k}}(\bar{r}) = u_{\bar{k}}(\bar{r}+\bar{r}_n) \rightarrow$$

So, we get. So, that we can therefore, write psi k of r as sigma g c k minus g E to the power I k minus g dot r.

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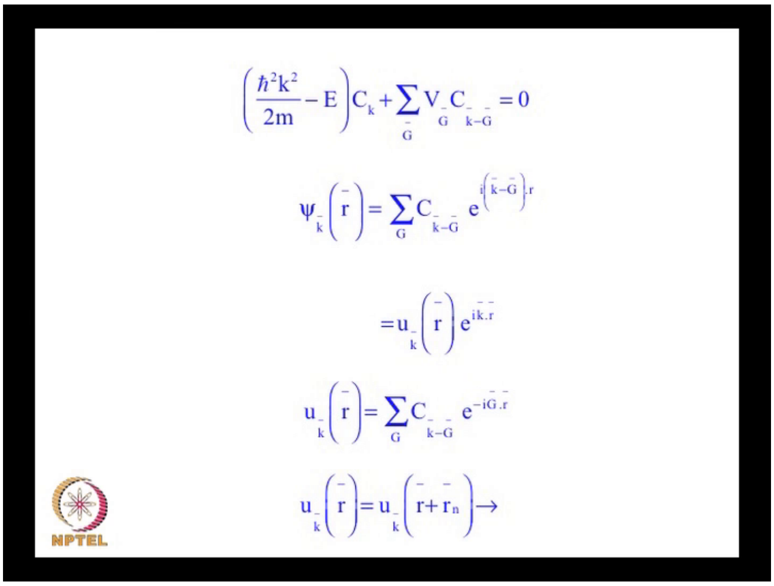

$$\left(\frac{\hbar^2 k^2}{2m} - E\right) C_k + \sum_{\bar{G}} V_{\bar{G}} C_{\bar{k}-\bar{G}} = 0$$

$$\psi_{\bar{k}}\left(\bar{r}\right) = \sum_{\bar{G}} C_{\bar{k}-\bar{G}}\, e^{i\left(\bar{k}-\bar{G}\right).r}$$

$$= u_{\bar{k}}\left(\bar{r}\right) e^{i\bar{k}.\bar{r}}$$

$$u_{\bar{k}}\left(\bar{r}\right) = \sum_{G} C_{\bar{k}-\bar{G}}\, e^{-i\bar{G}.\bar{r}}$$

$$u_{\bar{k}}\left(\bar{r}\right) = u_{\bar{k}}\left(\bar{r}+\bar{r}_n\right) \rightarrow$$

Which can also be written as u k of r a to the power i k dot r where u k of r is. So, we get the automatic property that the wave function psi k of r this modulator is a free electron wave function E to the power i k dot r modulator by the function u k of r such that u k of r equals u k of r plus r n. So, this as the modulating function as the periodicity of the lattice and so this is known as black wave function. So, the consequences of translational invariance of the periodic crystalline lattice is that the wave function psi k r is no longer the free electron plane wave function E to the power i k dot r that E to the power i k dot r modulated by the u k of r which is also translational invariance. And this is the form of the black wave function which we should use in our description of the energy Eigen values of an electron moving in a perfectly periodic potential. So, this is step one this is one important result which we will use in our discussion of the formation of so-called energy bands in solids.

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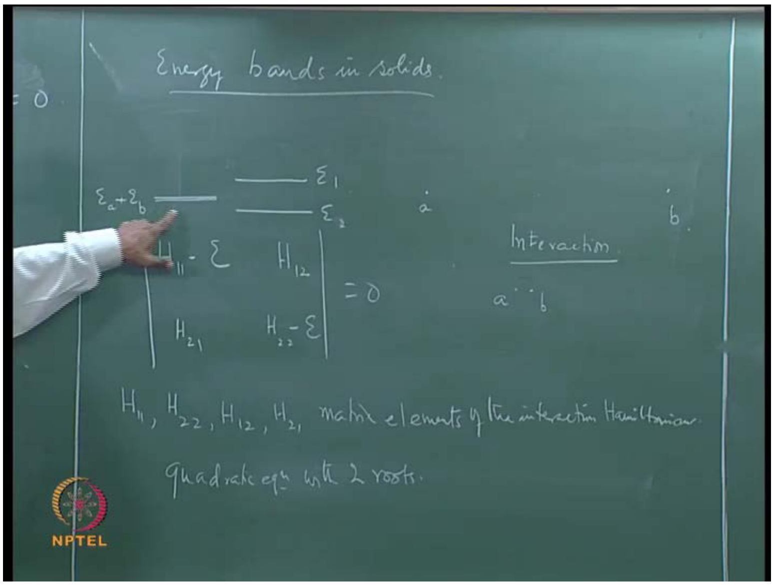

So, we move on to the discussion of energy bands in solids. In this discussion, we have to answer the question how bands f found the already saw in our discussion of the energetic of a homo nuclear diatomic molecule that if you have two molecule which are a far apart and therefore, non-interacting. The energy Eigen value of the two atom system is just twice the energy of the individual atoms and I am showing them together here in the form in which they are regenerate. So, this is energy of E a plus E b wave a and b are atoms which are no interacting now as the atoms are brought together we saw that the atom start interacting we turn on an interaction interact atomic interaction the electronic and nucleolus the electron and nucleates start interacting by as a coulomb potential. So, this interaction many it turn on and the two molecules come close together then we saw that the energy Eigen value is going to be given by the secular determinant where H 1 1 H 2 2 H 1 2 and H 2 1 are matrix elements of the interaction potential. Or interaction Hamiltonians between the individual atomic states represented by psi 1 psi 2. So, solving this we see that we get a quadratic equation with two root.

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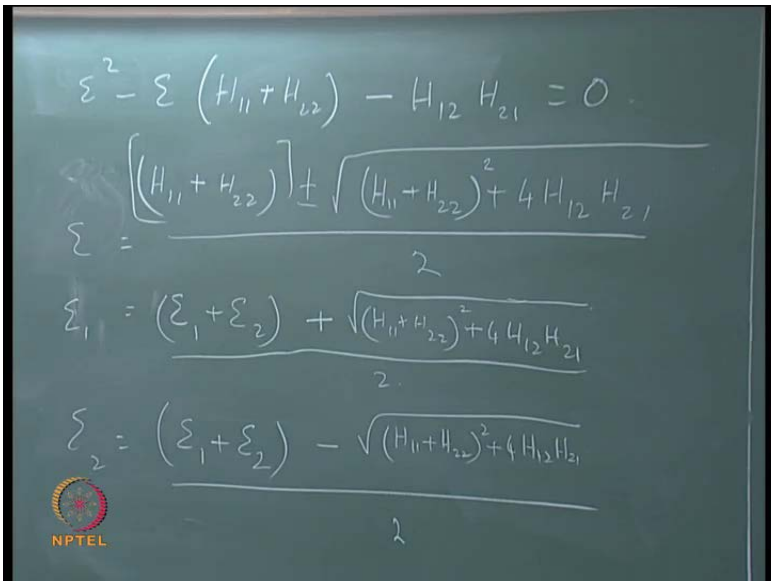

$$\varepsilon^2 - \varepsilon\left(H_{11} + H_{22}\right) - H_{12}H_{21} = 0$$

$$\varepsilon = \frac{\left[\left(H_{11} + H_{22}\right)\right] \pm \sqrt{\left(H_{11} + H_{22}\right)^2 + 4H_{12}H_{21}}}{2}$$

$$\varepsilon_1 = \frac{\left(\varepsilon_1 + \varepsilon_2\right) + \sqrt{\left(H_{11} + H_{22}\right)^2 + 4H_{12}H_{21}}}{2}$$

$$\varepsilon_2 = \frac{\left(\varepsilon_1 + \varepsilon_2\right) - \sqrt{\left(H_{11} + H_{22}\right)^2 + 4H_{12}H_{21}}}{2}$$

So, these quadratic equation has this form for which the roots are. So, this shows this will be this is the H 1 1 plus H 2 2 is what we call E 1 plus E 2 these are the energies of individual non interacting atoms and the resulting energy. Now in the presents of the interaction one of this is E one is plus square root of H 1 1 plus H 2 2 square plus 4 k 1 2 H 2 1.

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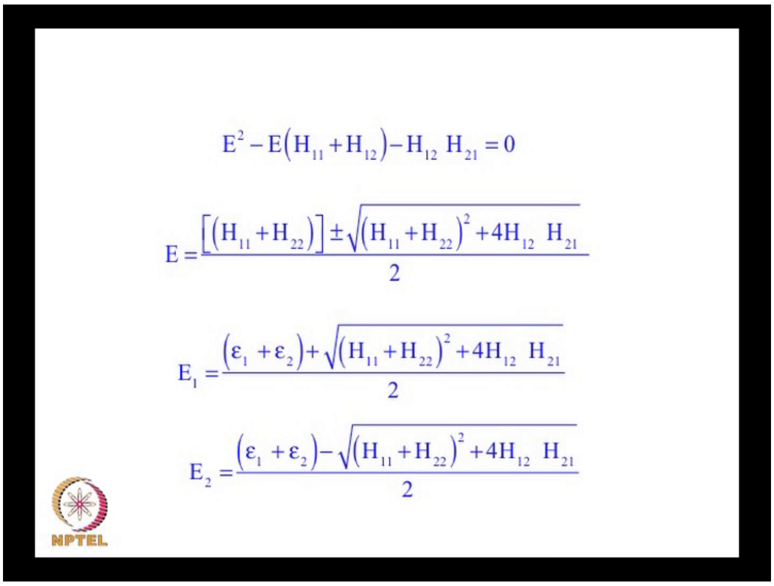

$$E^2 - E\left(H_{11} + H_{12}\right) - H_{12}\ H_{21} = 0$$

$$E = \frac{\left[\left(H_{11} + H_{22}\right)\right] \pm \sqrt{\left(H_{11} + H_{22}\right)^2 + 4H_{12}\ H_{21}}}{2}$$

$$E_1 = \frac{\left(\varepsilon_1 + \varepsilon_2\right) + \sqrt{\left(H_{11} + H_{22}\right)^2 + 4H_{12}\ H_{21}}}{2}$$

$$E_2 = \frac{\left(\varepsilon_1 + \varepsilon_2\right) - \sqrt{\left(H_{11} + H_{22}\right)^2 + 4H_{12}\ H_{21}}}{2}$$

Yes and the other one will be E 2 will be minus. So, there are two routes one corresponding to a lower value corresponding to the negative sign there, and a higher energy value corresponding to… So, these are the E 2 E 1. So, you see that any interaction when it is stand on the two atom systems the energy level are split into in a such a way, the two fold degenerate is lifted and there are two non-degenerated energy levels one the higher energy Eigen value, and another with the lower energy Eigen value. Now this is the situation when two atoms interact. We are now considering the periodic potential due to the entire lattice of all the ten to power 23 electrons. So, these are going to give you a large number of interaction of the same kind the solid is after all large molecule.

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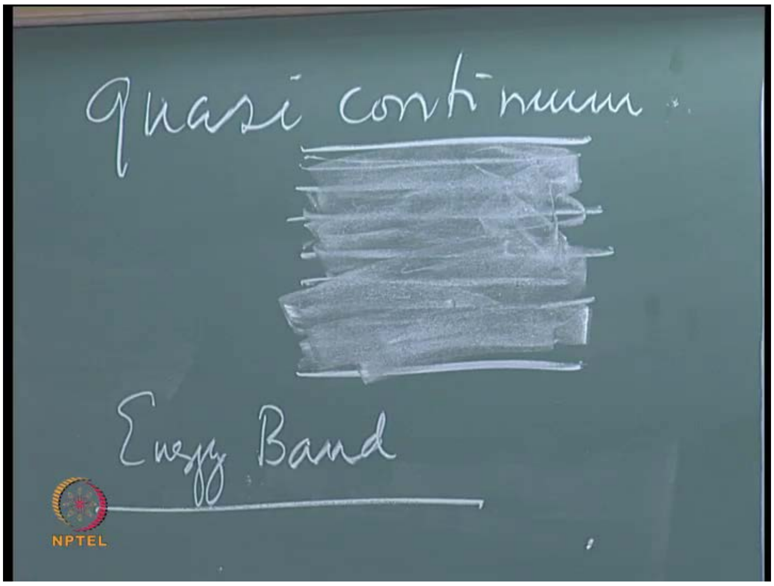

So, we are going to have a large number of splitting in this. So, of this finally, becomes a quasi I continuum when the number of interaction is very large so. This is a quasi I continuum. So, this continuum what we call an energy band in the presence of the perfectly periodic crystalline potential the electron energy going to sprodon into the form of energy bands. So, this is the mechanism of energy bands in order to discuss the detailed nature of the energy band.

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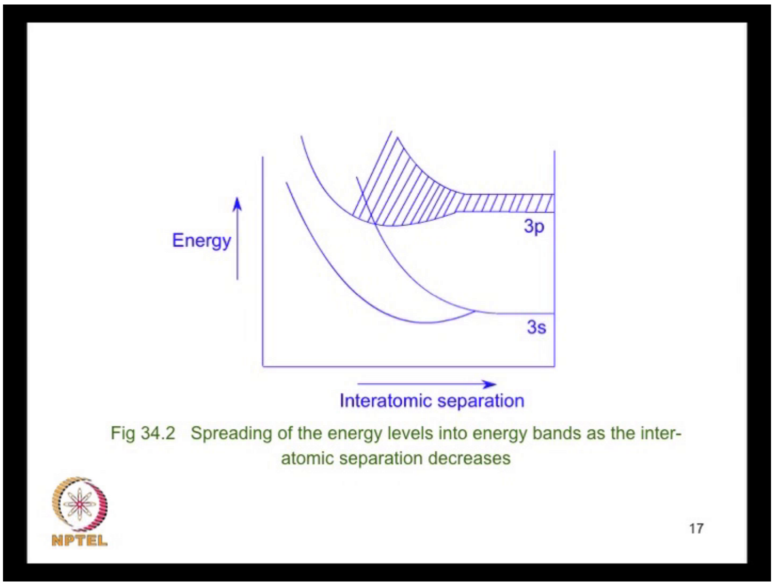

Fig 34.2 Spreading of the energy levels into energy bands as the inter-atomic separation decreases

Energy band it is necessary to go a little for other this is only a qualitative description of the interaction. Now let us consider a specific model in which we will be position to calculate the energy band structure.

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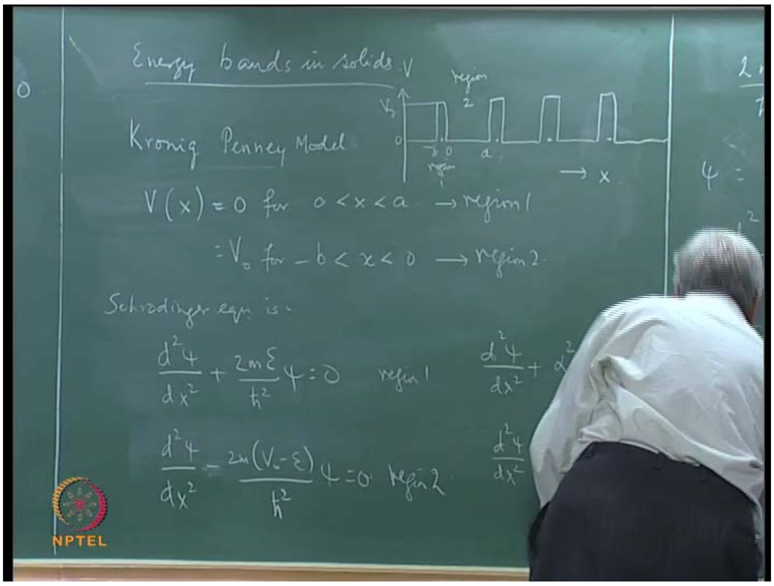

Energy bands in solids

Kronig Penney Model

$V(x) = 0$ for $0 < x < a$ → region 1

$= V_0$ for $-b < x < 0$ → region 2

Schrodinger eqn is :

$$\frac{d^2\psi}{dx^2} + \frac{2mE}{\hbar^2}\psi = 0 \quad \text{region 1} \qquad \frac{d^2\psi}{dx^2} + \alpha^2$$

$$\frac{d^2\psi}{dx^2} - \frac{2m(V_0 - E)}{\hbar^2}\psi = 0 \quad \text{region 2} \qquad \frac{d^2\psi}{dx^2}$$

So, this model is simplify one-dimensional model known as Kronig-Penney model. This discusses the motion of the electron in is one-dimensional potential which is 0 for 0 less than X less than area.

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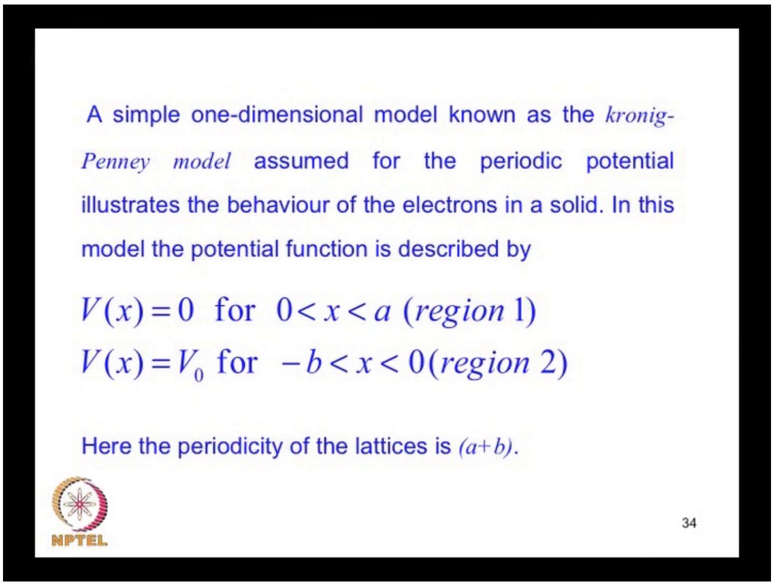

A simple one-dimensional model known as the *kronig-Penney model* assumed for the periodic potential illustrates the behaviour of the electrons in a solid. In this model the potential function is described by

$$V(x) = 0 \quad \text{for} \quad 0 < x < a \ (region\ 1)$$
$$V(x) = V_0 \ \text{for} \quad -b < x < 0 (region\ 2)$$

Here the periodicity of the lattices is $(a+b)$.

And equals V 0 for minus b less than a less than a. So this is known as less than 0 region one, this is region two pictorially this mean that we have atoms which are situated like this.

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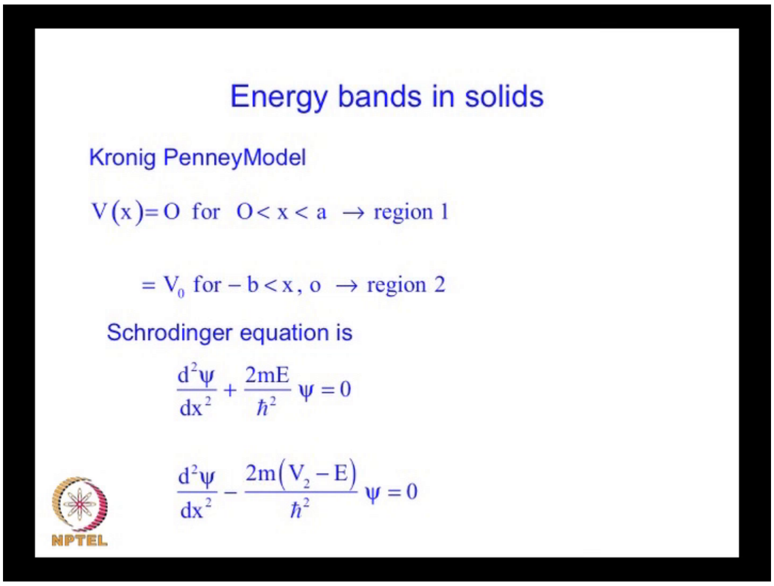

Energy bands in solids

Kronig PenneyModel

$$V(x) = O \ \text{for} \ O < x < a \ \rightarrow \text{region 1}$$

$$= V_0 \ \text{for} - b < x, o \ \rightarrow \text{region 2}$$

Schrodinger equation is

$$\frac{d^2\psi}{dx^2} + \frac{2mE}{\hbar^2}\psi = 0$$

$$\frac{d^2\psi}{dx^2} - \frac{2m(V_2 - E)}{\hbar^2}\psi = 0$$

And then you have a potential which is 0 here potentially is represented here which is 0 and when it is reaches the neighborhood of ion core then the potential goes up like that. So, this is V 0 this is minus b this is 0 this is a.

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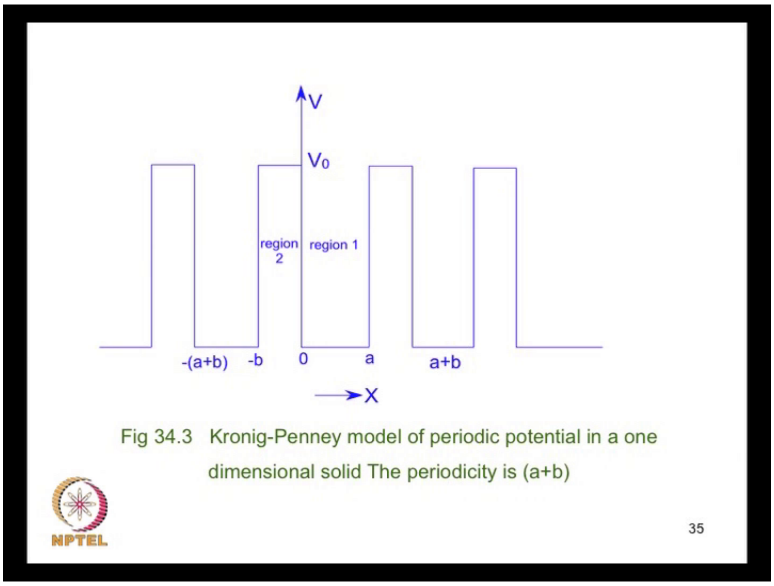

Fig 34.3 Kronig-Penney model of periodic potential in a one dimensional solid The periodicity is (a+b)

So, in the torsion the Schrodinger equations in one-dimensional d square psi d x square 2 two m V by H cross square psi equal 0 this is region one where V of x is 0 then. So, this is region one this is region 2 this region one this is region 2 let us first short and write 2 m E by H cross square.

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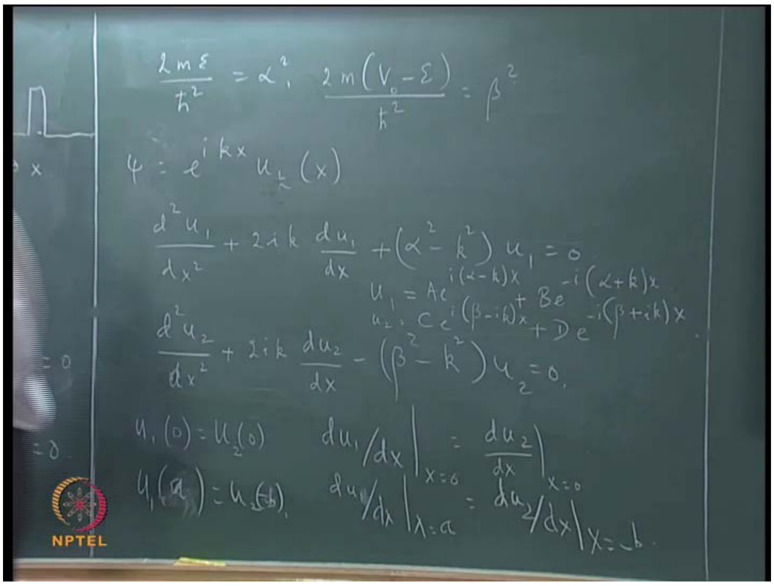

$$\frac{2m\mathcal{E}}{\hbar^2} = \alpha^2; \quad \frac{2m(V_0-\mathcal{E})}{\hbar^2} = \beta^2$$

$$\psi = e^{ikx} u_k(x)$$

$$\frac{d^2u_1}{dx^2} + 2ik\frac{du_1}{dx} + (\alpha^2 - k^2)u_1 = 0$$

$$u_1 = Ae^{i(\alpha-k)x} + Be^{-i(\alpha+k)x}$$

$$u_2 = Ce^{i(\beta-ik)x} + De^{-i(\beta+ik)x}$$

$$\frac{d^2u_2}{dx^2} + 2ik\frac{du_2}{dx} - (\beta^2 - k^2)u_2 = 0.$$

$$u_1(0) = u_2(0) \quad du_1/dx\Big|_{x=0} = \frac{du_2}{dx}\Big|_{x=0}$$

$$u_1(a) = u_2(-b), \quad du_1/dx\Big|_{x=a} = du_2/dx\Big|_{x=-b}.$$

Yes alpha square and two m into V naught minus E by H cross square as beta square. So, that this becomes and this is now we have the black solution the black form which we discuss already in the form. So, that substituting this and making differentiation and substitute that we get the two equation these equation become and there u r, u 2 are the function u here in the region 1 2. So, these are the equation to be satisfy solved for u and u 2 the solution u and u 2 should satisfy boundary condition which are such that at the interface were at minus b at 0 and a they have to be matched in other words u 1 of 0. They matched two wave function match at x equal to 0.

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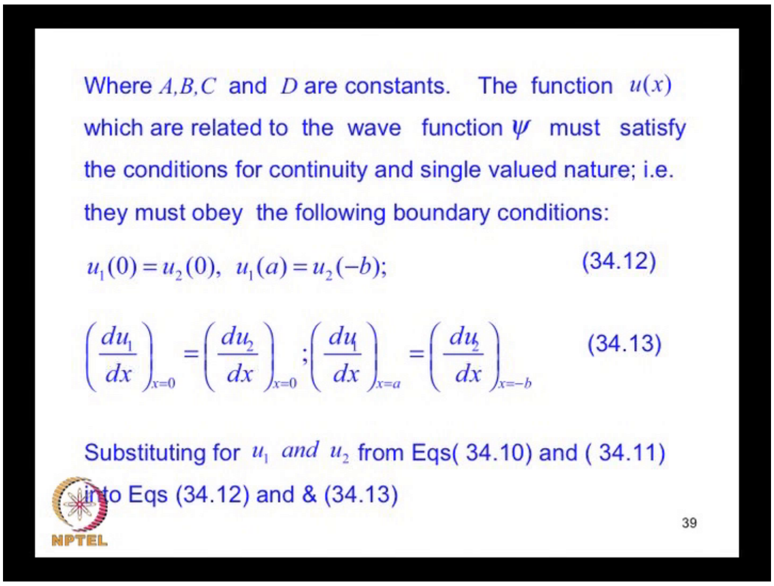

Where A, B, C and D are constants. The function $u(x)$ which are related to the wave function ψ must satisfy the conditions for continuity and single valued nature; i.e. they must obey the following boundary conditions:

$$u_1(0)=u_2(0),\ \ u_1(a)=u_2(-b); \qquad (34.12)$$

$$\left(\frac{du_1}{dx}\right)_{x=0}=\left(\frac{du_2}{dx}\right)_{x=0};\left(\frac{du_1}{dx}\right)_{x=a}=\left(\frac{du_2}{dx}\right)_{x=-b} \qquad (34.13)$$

Substituting for u_1 *and* u_2 from Eqs(34.10) and (34.11) into Eqs (34.12) and & (34.13)

And there are again match at u 1 of minus B equals u 2 of a for u 1 of a. These 2 minus B this a consequent of translation in variance and also condition on the derivatives d u one d x at the x equal to 0 matches d u 2 by d x at x is equal to 0. And a similar condition on d u 1 by d x x equal to a equals d u 2 by d x at x equal to minus b. If I take the forms this gives forms u 1 equals a E to the power i alpha minus k x plus d E to the power of minus i alpha plus k x. And u 2 is c to the power I beta prime by k x plus d E to the power minus i beta plus i k x. So, we required the solution u 1 and u 2 to satisfied this condition and that gives you a determinant which a 4 by 4 determinant because 4 conditions there and which when expanded leads to the following condition to be satisfied.

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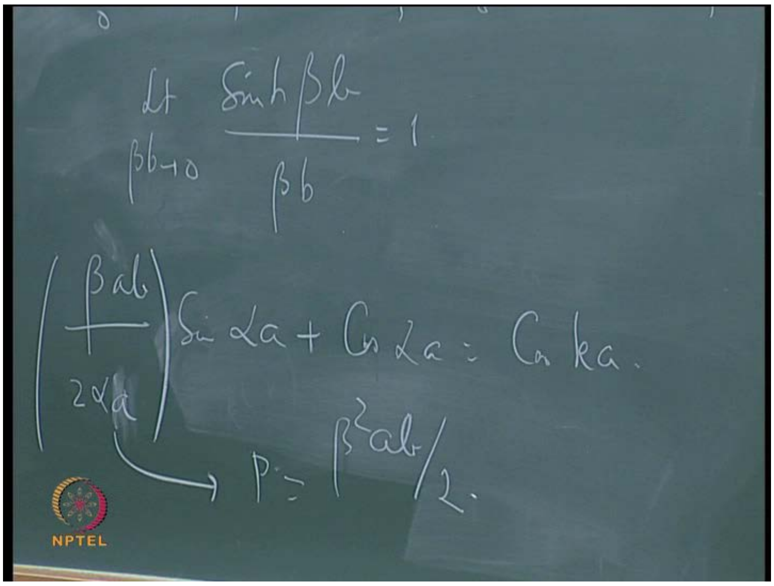

$$\underset{\beta b \to 0}{\text{Lt}} \frac{\sinh \beta b}{\beta b} = 1$$

$$\left(\frac{\beta a b}{2\alpha a}\right) \sin \alpha a + \cos \alpha a = \cos ka.$$

$$\longrightarrow P = \beta^2 ab/2.$$

Namely beta square by alpha square by 2 alpha beta sin alpha a sin H of beta b plus cos alpha a cosign hyperbolic beta b equal to cos k a plus b. So, that will be the condition to be satisfied which is got by a expanding by the four by four determinants now we specify to the situation where V naught tends to infinity and b tends to 0 in other words it is extremely thin barrier it is infinitely high.

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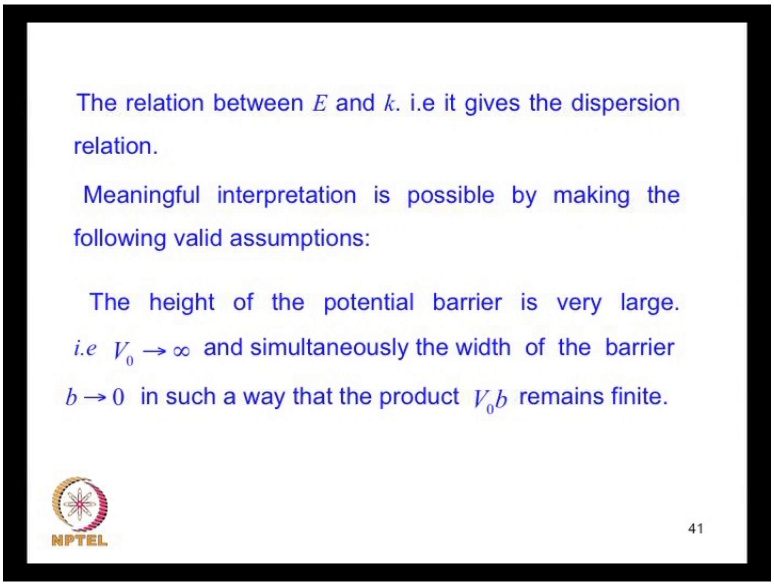

The relation between E and k. i.e it gives the dispersion relation.

Meaningful interpretation is possible by making the following valid assumptions:

The height of the potential barrier is very large. $i.e\ V_0 \to \infty$ and simultaneously the width of the barrier $b \to 0$ in such a way that the product $V_0 b$ remains finite.

Such that V naught b remains this case we get limit beta b 10 into 0 sin H beta b by b equal to 1 and therefore, the derivative condition b sin alpha a plus cos alpha a equals cos k a.

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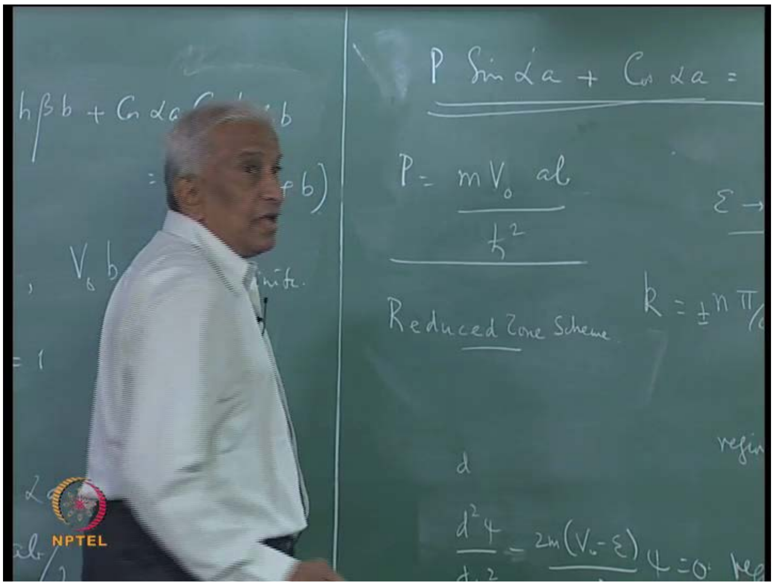

So, this p is nothing but m V naught a b by H cross square. So, this is the parameter which involves the highest of the potential barrier and the thickness of the potential barrier. So, this is the basic condition which determines the energy Eigen values.

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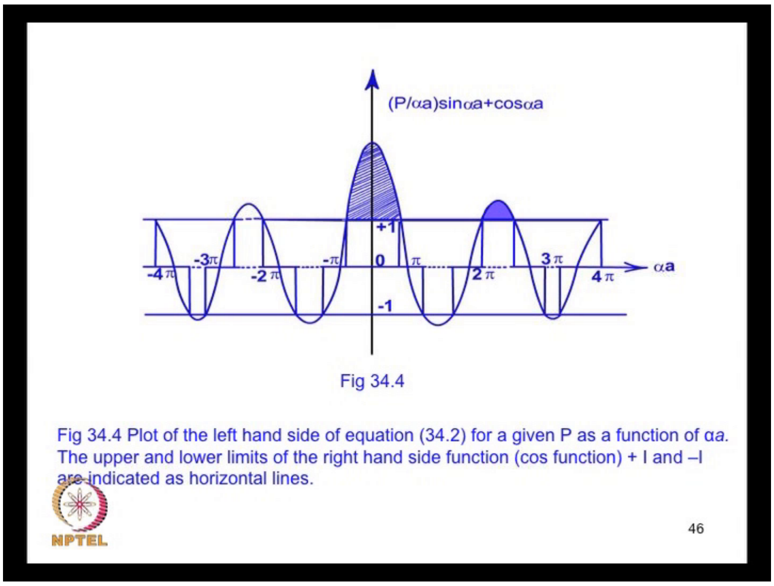

Fig 34.4

Fig 34.4 Plot of the left hand side of equation (34.2) for a given P as a function of αa. The upper and lower limits of the right hand side function (cos function) + I and –I are indicated as horizontal lines.

We can see the nature of this energy band s by looking at the graphical representation of these energy bands. So, the figure shows the plate of the right hand side this side of this equation for a given value of p as a function of alpha a. So, we can see that there shaded portions left hand side is plotted since the right hand side is just cosign function. So, it cannot go beyond the value is a plus one of minus one and therefore, you find shaded regions in the figure correspond to such values of cosign k a which are unreasonable and therefore, are forbidden they are not allowed. So, you find that energy values get into two in two regions one the un shaded one corresponding to the allowed energy values and the shaded regions which corresponds to the forbidden regions the energy Eigen values.

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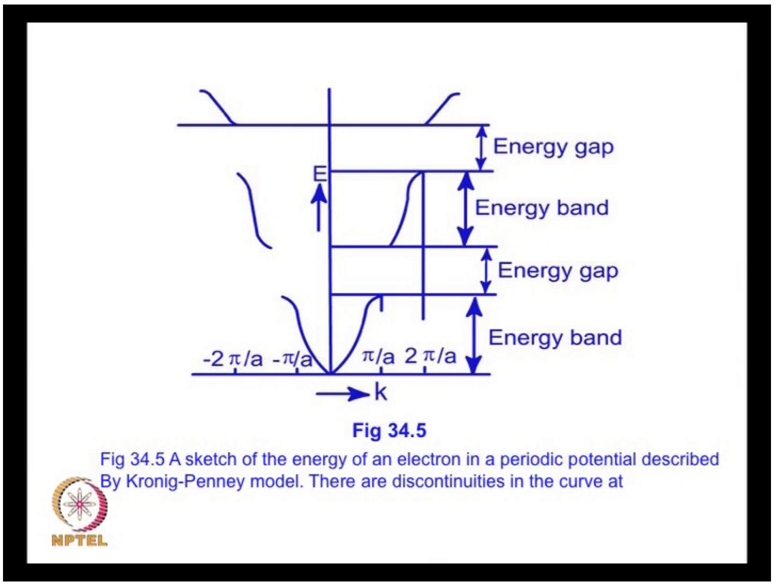

Fig 34.5

Fig 34.5 A sketch of the energy of an electron in a periodic potential described By Kronig-Penney model. There are discontinuities in the curve at

So, these energy Eigen values when plotted look like this they are shown the energy E versus k curve we shown in. So, this gives the energy versus the wave vector for an electron in a periodic potential described by the chronic penny model. So, you can see that there are discontinuities at k equal to pi by a and k equal to minus pi by a and then k equal to two pi by a k equal to minus q pi by a and so on. So, in general, for all k equal to n pi by a plus or minus there are discontinuities in a energy. So, the energy Eigen value goes from the value suddenly it is this and all the energy Eigen values in this region are not allowed.

So, these are the allowed energy Eigen values these are the forbidden energy Eigen values in the gap region again these are allowed set up Eigen values then followed by energy gap again in the next band so on for the third band and so on. So, this goes on and we find that this can be represented a bit more effectively in the. So, called reduced zones scheme this only means that the states k and k plus or minus in into 2 pi by a n into pi by a.

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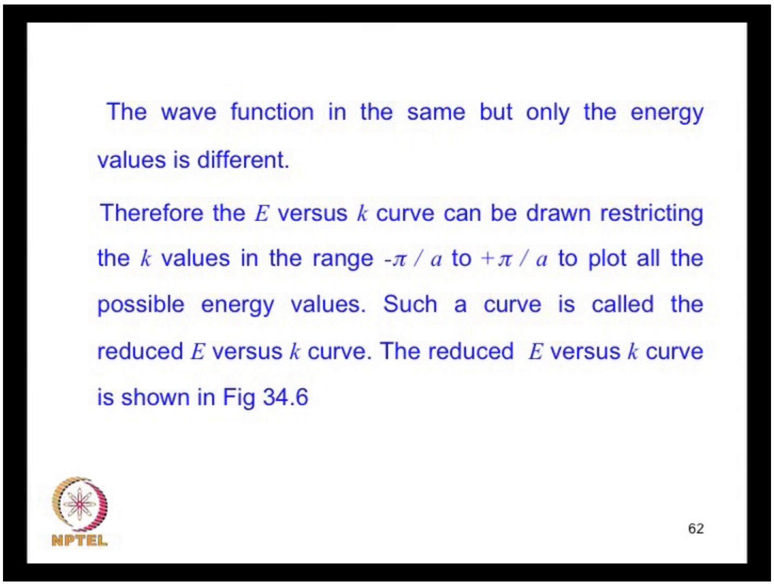

The wave function in the same but only the energy values is different.

Therefore the E versus k curve can be drawn restricting the k values in the range $-\pi / a$ to $+\pi / a$ to plot all the possible energy values. Such a curve is called the reduced E versus k curve. The reduced E versus k curve is shown in Fig 34.6

These are all equal and they are identical functions while the functions while the energies are different. So, the energies are different, but they are discovered by the same function. So, these verses k curve can be done by restricting the k values in the range minus pi by a to plus pi by a

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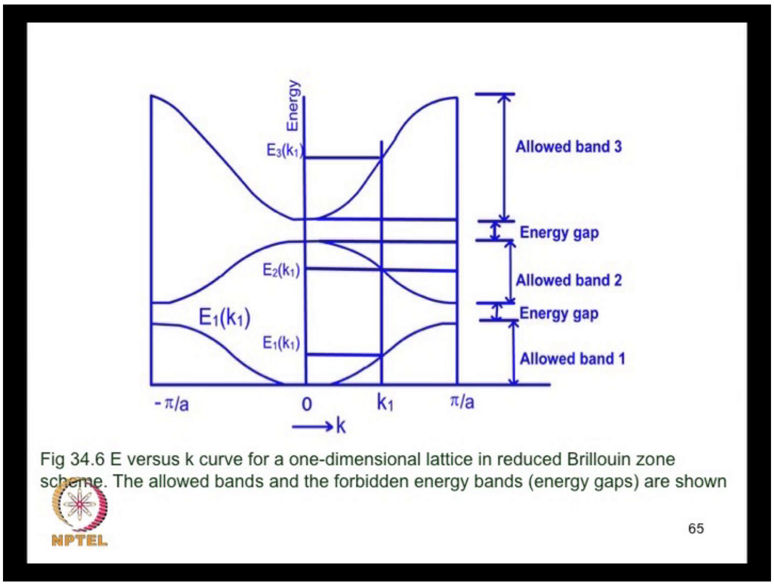

Fig 34.6 E versus k curve for a one-dimensional lattice in reduced Brillouin zone scheme. The allowed bands and the forbidden energy bands (energy gaps) are shown

And all the energy values can be plotted within this region. So, such a plot issue shown in figure where the first band as energies shown in the lowermost curve these are we allowed value and then E two is the corresponding energy values for the second band plotted in the reduced came therefore, there is a gap between these two. So, there is an energy gap and then the next allowed band comes here that is the two k and similarly E three k with a gap here. So, this shows the entire energy band structure within this first Brillouin zone which is the region between minus pi by a and plus pi by a. So, this is this describe the band structure the typical band structure. So, the Kernig-Penny model gives as an easy way to understand the formation of energy bands in periodic solid.

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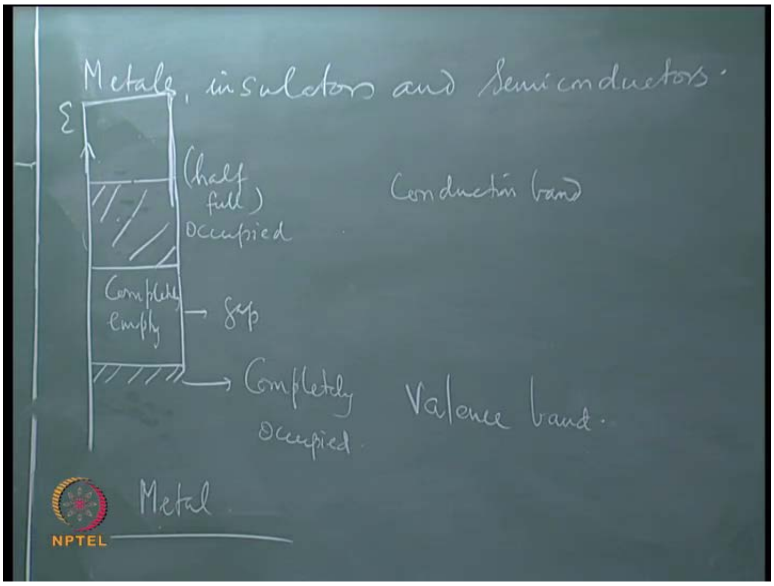

And this is very important in a discussion of the property of metals insulators and semiconductor these are new clause of materials which we are going to discuss from now on in a unified way hoe do you discuss this the matter let me just sketch the band structure in a simple way. So, this is the E energy and this is the band structure in a very crude form.

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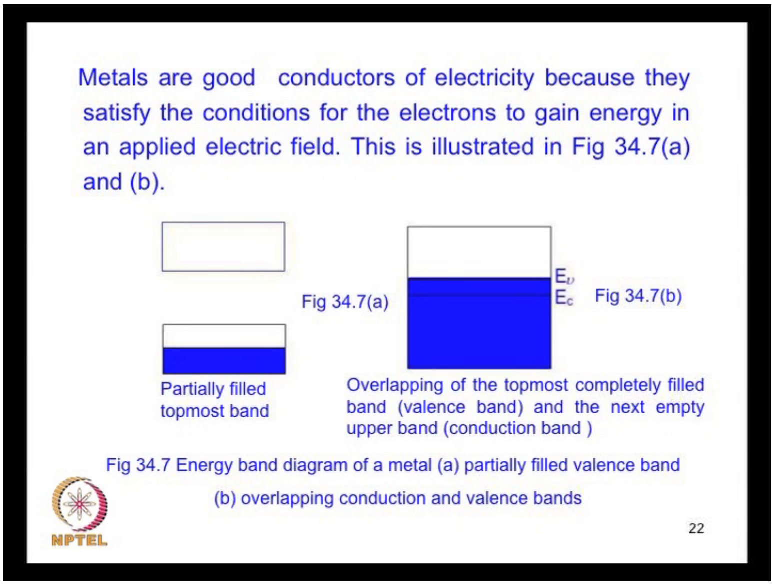

Metals are good conductors of electricity because they satisfy the conditions for the electrons to gain energy in an applied electric field. This is illustrated in Fig 34.7(a) and (b).

Fig 34.7(a)

Partially filled topmost band

Fig 34.7(b)

Overlapping of the topmost completely filled band (valence band) and the next empty upper band (conduction band)

Fig 34.7 Energy band diagram of a metal (a) partially filled valence band (b) overlapping conduction and valence bands

So, we have states laying here this is empty and there are states here. So, these are states which are occupy and these are states which are forbidden and therefore, this states allow forbidden an occupy empty and this is an occupied band the bands. And of course, the extent of to this energy value and it is only of full this band is completely occupy the lower bands and this is completely empty this is the gap. So, this is the picture of a metal in a metal there is a completely occupy band separated from a partially occupied or of full conduction band this is known as the valance band and this is the conduction band. So, the valance band is completely occupied whenever a band is completely occupied states are free for an electron to get into because of Pawley's fusion principle and. So, conduction in a such a band is not possible the electron cannot move on one state to another similarly if there is a completely empty band that is also something in which there are no electrons therefore, is there is no conduction.

So, for conduction to be possible in a material request have a band structure with an uppermost band which is only partially feel in this case the metal is only of filled and therefore, of the band is empty and off of the band is occupied. So, the electrons the conduction electron is can move from the occupied states into the empty states there by facilitating conduction. So, conduction is possible. So, this is the band structure which renders a metal conducting coming to the case of an insulators and insulators how is its band structure.

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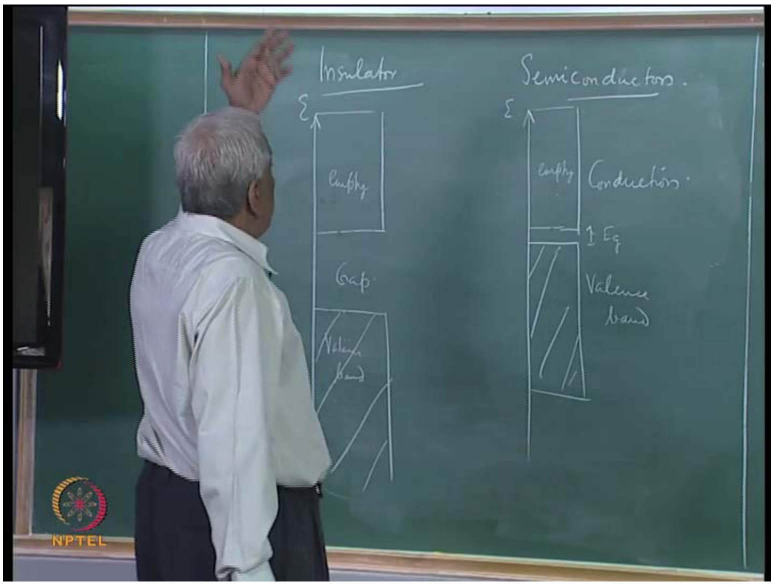

Band structure again we shown in schematically in this way. So, you have a upper band and a lower band this is a gap. So, this is the valence band which is completely occupied and a conduction band which is empty, but separated The conduction band which is empty is separated from the valance band which is completely occupy by a very large gap energy gap. So, for carriers to into this empty band from in the occupied band they have to cross overcome this barrier produced by these energy gap and they have to get in from the state in the valance band they have to get into the state in the empty unoccupied band upper band. So, this is possible only there as the energy which is more than the gap energy and then an insulators is does not happen and therefore this is not conducting.

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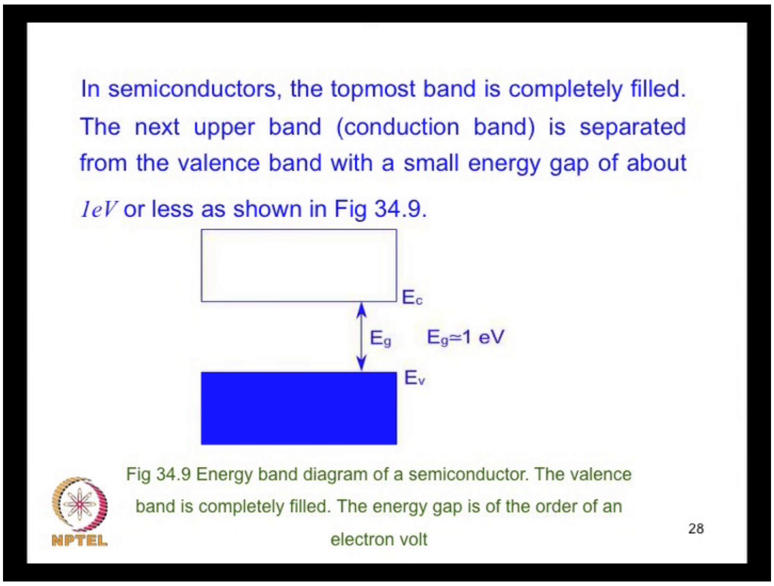

In semiconductors, the topmost band is completely filled. The next upper band (conduction band) is separated from the valence band with a small energy gap of about $1eV$ or less as shown in Fig 34.9.

Fig 34.9 Energy band diagram of a semiconductor. The valence band is completely filled. The energy gap is of the order of an electron volt

Now we come to an another interesting class of material which we have not talked about so far which is known as semiconductors. So, here the band structure is very similar that of an insulator. And there is an valance band below which is completely occupied with an energy gap which in contrast to an insulator the energy gap is as a very small value. In other words, the occupied valance band is separated from the unoccupied conduction band only by an extremely small amount of energy of the order of an electron hole. So, it is easily possible for carriers to get excited across the gap from getting to conduction band. Therefore, they neither an insulator nor a metal like this, but they are semiconducting.

So, this is the new class of material, which will be discussing from now on. And the band structure theory, the theory of energy band provides a convenient mechanism or convenient way to understand the difference between an insulators, a metal and a semiconductor from the point of view of their band structures. And there relate these electronic band structure to the nature of the conduction band in these material. We will discuss semiconductors in the next session.

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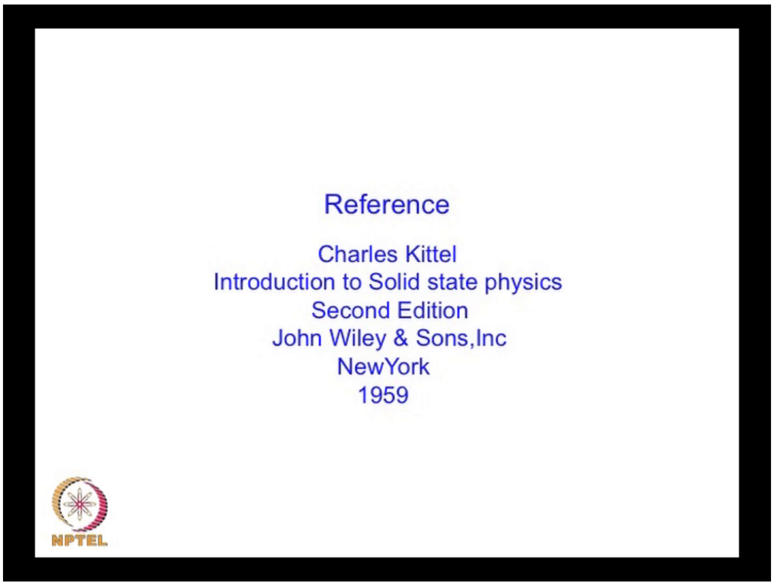

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