**Crystals, Symmetry and Tensors**
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**Lecture 1b**
**Lattice and Motif**

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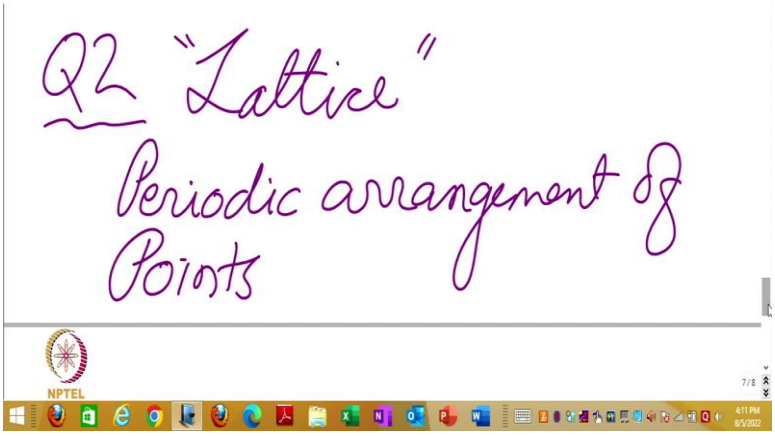


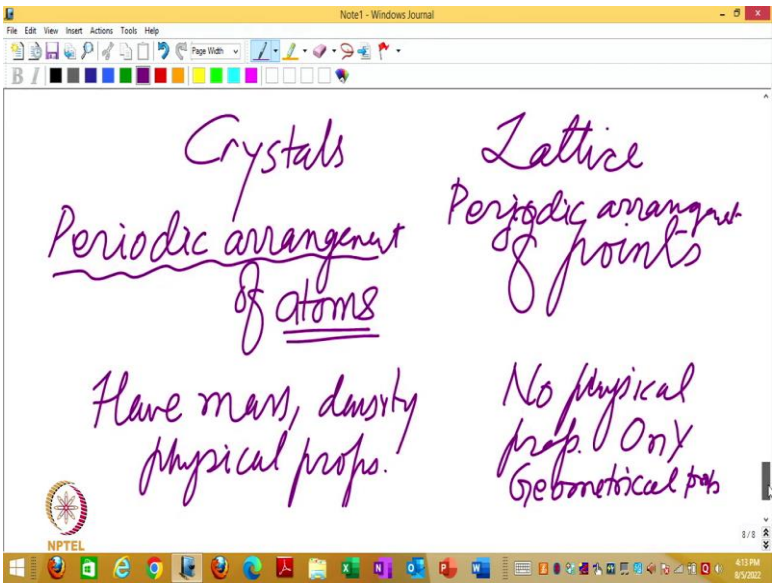


So, let us say that we have understood, what is a crystal periodic arrangement of atoms. Then what is a lattice? This why we are discussing it very slowly and why this is important, because these two have very similar meaning and it is easy to mix up and the web is full of all sorts of mix up between these two concepts and from not by some local dhabas, but big five star restaurants of academics, you will find this mistake of mixing up calling lattice where they should have called crystal and calling it crystal where they should have called it lattice.

We will see the examples later. But let us first define So, what is lattice? How is lattice different from crystal periodic arrangement of points, so that was periodic arrangement of atoms, this periodic arrangement of point. So, very easily you can see the difference between crystals and lattice arrangement of and because both are periodic that is where one mixes up that is where the danger of mixing up is there.

So, periodic arrangement of atoms is periodic arrangement of points. Now points you do not have mass so, lattice will not have mass, lattice will not have density, lattice will not have electrical conductivity. So, saying that electrical conductivity of cubic lattice itself is sort of not a precise statement only geometrically property lattice will have only geometrical properties, but both are periodic, periodic arrengementis also periodic.

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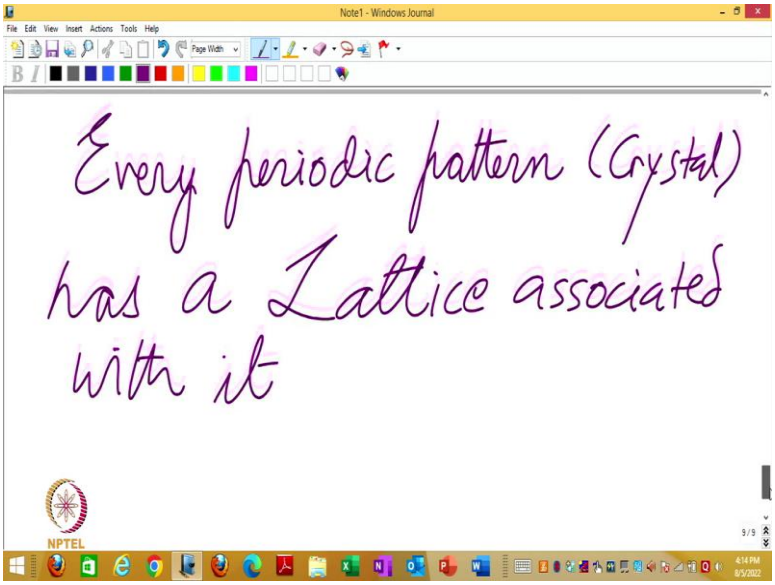


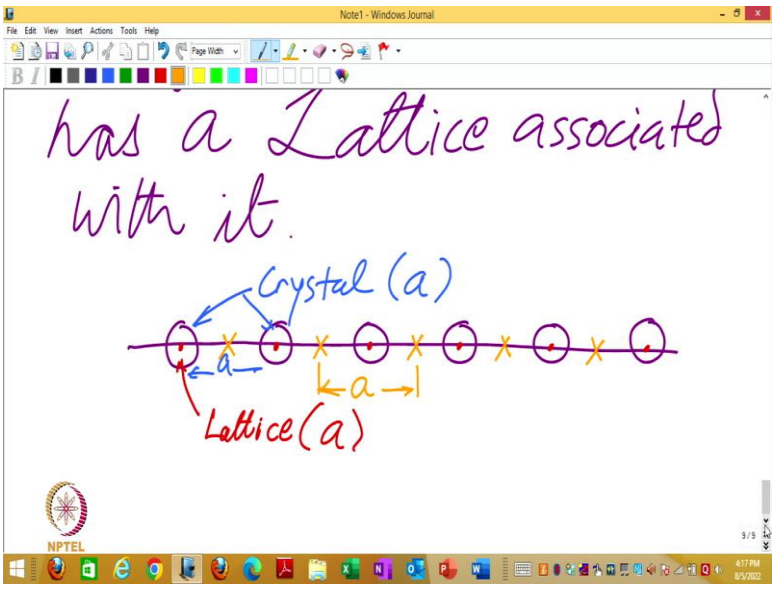

So, because of that periodicity they have something common. So, every lattice every periodic pattern crystal in particular has a lattice. So, let us get back to our let us get back to our 1d example. So, if I have 1d periodic arrangement of atoms that is a one dimensional crystal, but suppose, I select the centers of each atom so, then I get a periodic set of points. So, these points form a lattice and these atoms form crystal but what is the repeat period of crystal? What is the repeat period of atom, a. What is the repeat period of lattice, again a.

So, they have the same translational periodicity. So, when we say lattice of a pattern we are extracting a set of points, which have exactly the same periodicity as that of the pattern, then we say that that is a lattice of the pattern. You also saw that it was not important to choose important to start at any specific point, center of atom looks nice, but I can select midpoint of atoms also. If I select midpoint of atoms then the choice of origin which I told you I have selected a different origin but have I got a different lattice, in a way yes, different lattice we call it is shifted, but actually we will consider both of them identical lattice only shifting.

So, both are periodic set of points the dots and the cross both are periodic set of points with the same periodicity. So, they are representing the same lattice and both are connected to my original crystal. So, both are lattice of the pattern the difference is only the choice of origin.

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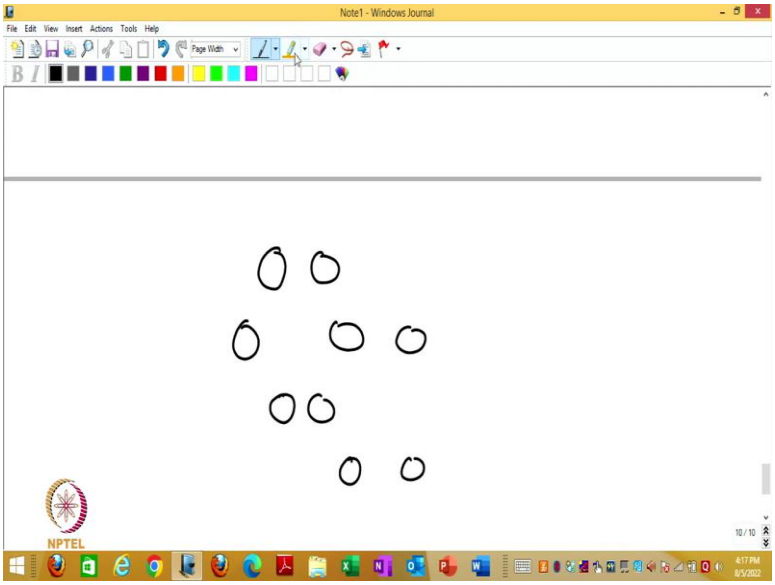
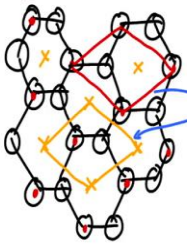


Note1 - Windows Journal

graphene.



identical rhombuses.
(unit cell)

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Note1 - Windows Journal

Crystal → Lattice (unique)

Periodic Pattern of atoms ≡ Motif

What is being being repeated?

Periodic set of points giving the periodicity of crystal

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Note1 - Windows Journal

Crystal = Lattice ⊕ Motif

"How to repeat" "What to repeat"

associate identical motif to each lattice point

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So, let us do this exercise now, for our graphene example it is better to draw the hexagonal grid otherwise I am going haywire. Here, if I want to figure out the equivalent point translationally equivalent point then if I select this center atom center of this atom, then I know that nearby was not translationally equivalent, so, I cannot select that. So, I will go and select the alternate ones.

So, center of all atoms is not forming a lattice now, only center of alternate atoms is forming a lattice in graphene. Again, it was not important to select the center of the atom, I could have selected the center of the hexagon where there is no atom and if I select the center of the hexagon again I am getting exactly the same lattice only shifted. You can see that by choosing what we call a unit cell you will get a rhombus unit cell and the size and shape of that rhombus will exactly be the same whether you select your red atoms centers or the cross points which are centers of the hexagon.

Identical rhombuses you know what it is called, but I was refraining from using it because we have not yet defined it as a unit cell. So, again either the red points or this cross points show the periodicity of the structure does not tell me what is the structure I could have repeated a single point also on this lattice. But if I repeat single point single atoms on this lattice, I will not get graphene to get the graphene I have to repeat a pair of atoms at these lattice point as we have seen.

So, we have got we have got lattice we have what crystal which was periodic pattern of atom and from there we got lattice which tells you the periodicity of the structure. Although, suppose I if I if I only give you the lattice, if I only give you the red points, and I do not say that I am talking about graphene I do not tell that you are repeating carbon atoms and I do not tell that you are repeating two carbon atoms. Will you be able to get the structure so, from crystal you can get back from crystal you can always derive a lattice, but from lattice to crystal is not a unique path.

So, this is unique but if you want to go back so some more information is required. And what is that information? What is being repeated, because lattice is giving you only the repeated structure. So, it is telling you something is being repeated something has this periodicity, the pattern has this periodicity, but it is not telling you.

What is the pattern consisting of? So, you need what is being repeated as additional information and this what is being repeated this is what is given a name and that is called a

motif. So, a sort of a sort of mathematical equation because we like mathematics although this is not ordinary plus we write crystal is equal to lattice which gives the periodicity plus motif which gives what is being repeated.

So, lattice tells you “how to repeat” motif tells you “what to repeat” and together they tell give you the repeated pattern and that is the crystal. So, this is one of the important central equation. But this plus as you can see this is not an arithmetic plus or a vector addition or a scalar addition this plus is our mental plus, where we are associating identical motif to each lattice point to each lattice point.