Introduction to Materials Science and Engineering
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Lecture - 2
Crystal geometry

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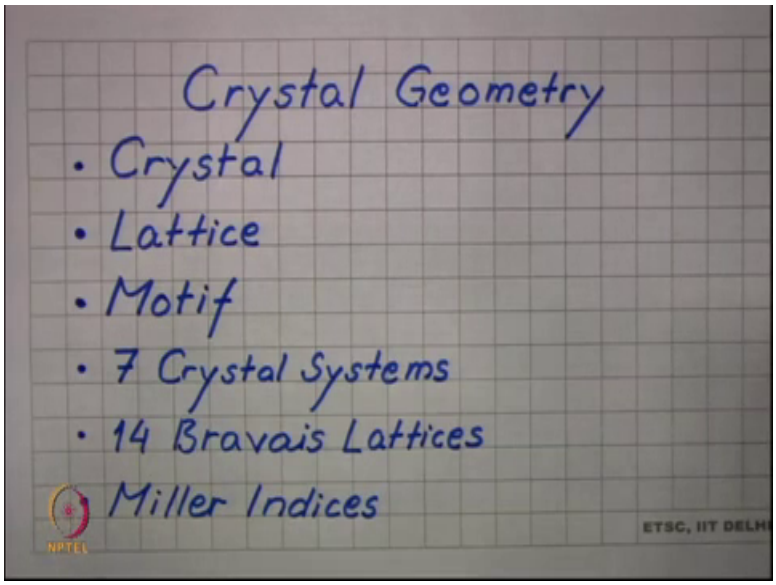

Welcome, today's topic is crystal geometry. In this there are several subtopics which we will discuss. Crystals, lattice, motif, 7 crystal systems, 14 bravais lattices and miller indices, we will begin with crystal and lattice two related concept, but quite often the distinction is not made clear and then it can get confused. So, we will spend some time on a very clear distinction between crystal and lattice motive, is the linking bridge between crystal and lattice. Afterwards we will focus mainly on lattice and see how the lattices can be classified into 7 crystal systems and 14 bravais lattices. And we will end this section with discussion of miller indices of directions and planes. We begin with the definition of crystal. What is a crystal?

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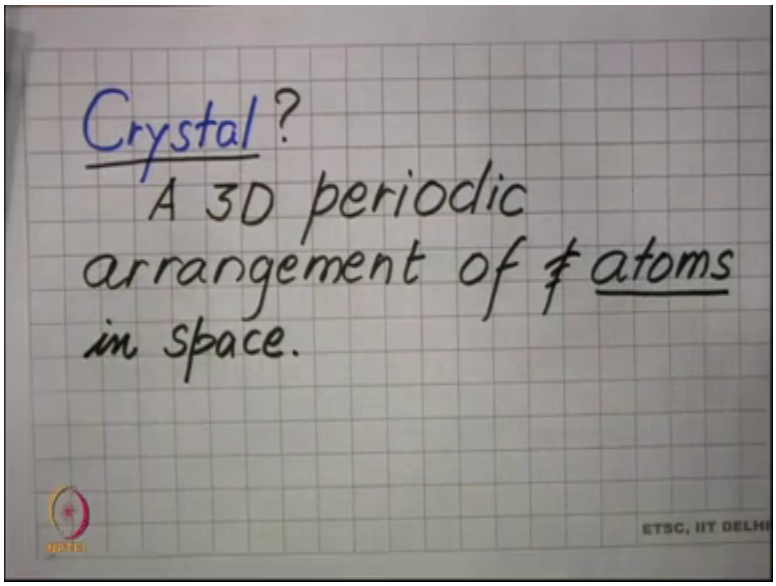

So, you can pause here and think about what is your definition or what is your concept of crystal. Before I gave my definition, we will define crystal as a 3 dimensional periodic arrangement of points of, sorry of atoms. A 3 dimensional periodic arrangement of atoms in a space will be called crystal, the related concept. Let me show first a model of what we mean by 3 dimensional periodic arrangement of atoms.

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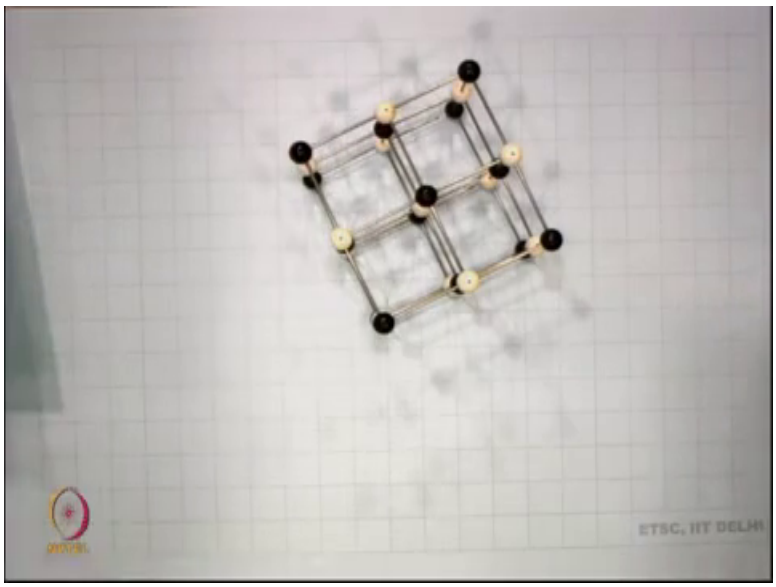

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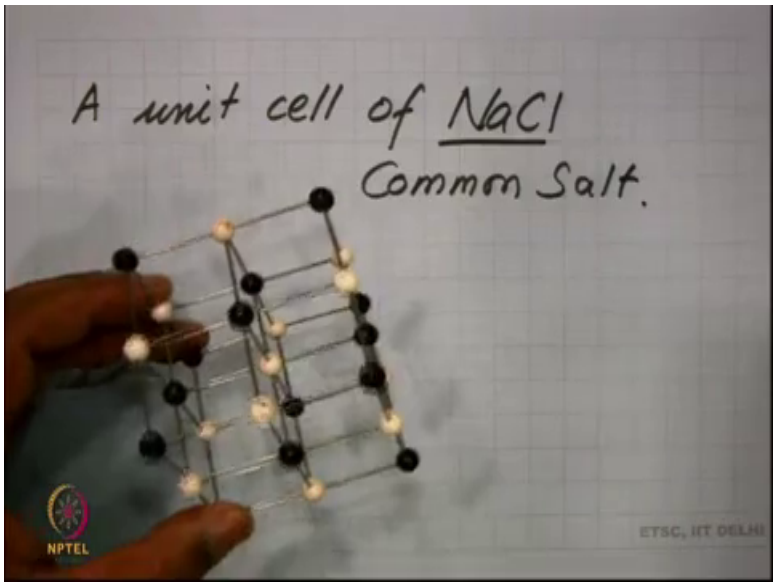

So, here is a unit cell of sodium chloride. So, this is unit cell of sodium chloride, the black, black atoms you can consider as chlorine. The white one says sodium. And what we mean by 3 dimensional periodic arrangement, that these chlorine and sodium atoms are repeating in each direction at equal distances. So, for example, if we look at, along the cube edge, we start with chlorine then after certain distance I find a sodium and then again chlorine.

And if I continue in this direction I will keep finding chlorine, sodium, chlorine, sodium, chlorine, sodium so on. So, that is what is meant by periodicity. So, in this direction I have periodic arrangement of chlorine and sodium. If I go along the face diagonal, if I go along the face diagonal, you see we are having chlorine chlorine chlorine. Again in this direction if I continue in the crystal, I will keep finding chlorine at these equal intervals same thing is true in all the direction.

So, I have a 3 dimensional periodic arrangement of sodium and chlorine atom represented by this unit cell, and this is the crystal of sodium chloride. Crystal of sodium chloride also known as common salt we will have. We will look at this unit cell and this crystal structure in more detail as we go along at the moment. I am showing you just as an example to begin with.

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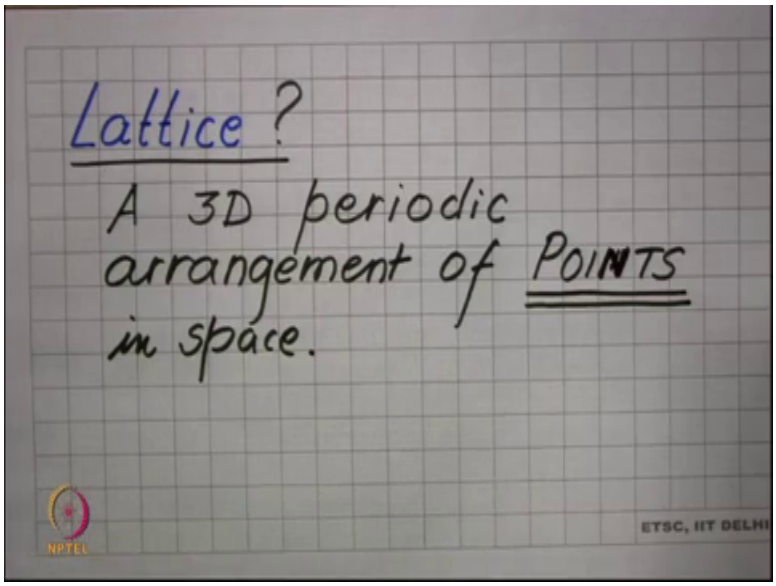

Now, I come to the related concept of lattice. What is a lattice, and how is it different from crystal. So, a lattice is a 3 dimensional periodic arrangement of points. 3 dimensional periodic arrangement of points in a space. So, the difference between crystal and lattice is, whether the points are being considered or atoms are being considered; otherwise both are periodic arrangement, 3 dimensional periodic arrangement. This is the reason for confusion between these two concepts.

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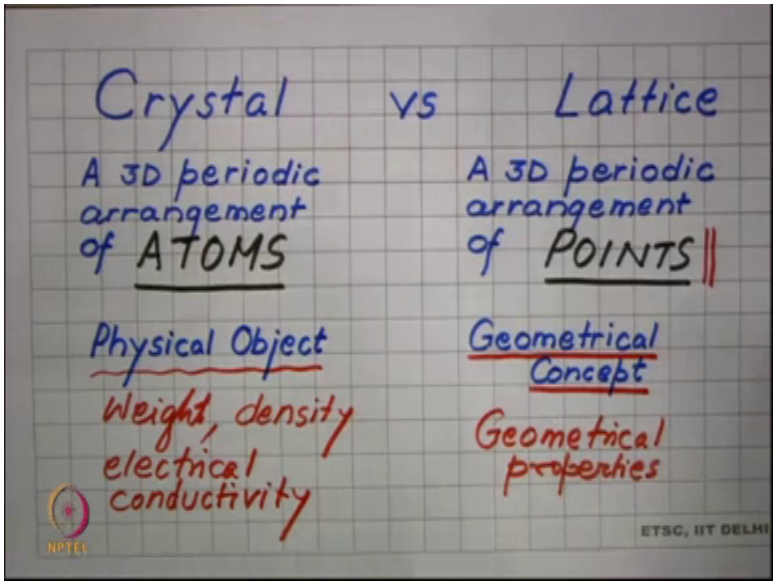

So, let us put that together, crystal we said a 3 dimensional periodic arrangement of atoms. Let me write that here lattice a 3 dimensional periodic arrangement of points. So, you can see a crystal will be a physical object. Atom is physical object. So, a crystal will be a physical object, it will have physical properties like weight. You can weigh a crystal, it will have density. You can measure it is electrical or thermal conductivity, and so on a lattice in contrast is a geometrical concept, because it is just a 3 dimensional periodic arrangement of points. So, it will not have any of these physical characteristics. You cannot weigh a lattice. You cannot find its density or electrical conductivity and so on. So, it has a geometrical concept we will have only. So, geometrical properties, we will make the distinction clear in more detail as we go along.

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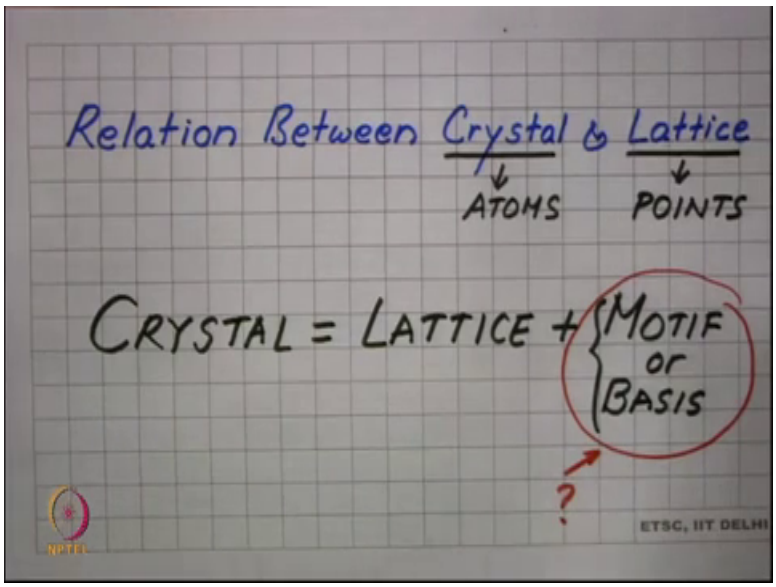

Now, what is the relationship between the crystal and lattice; both are 3 dimensional periodic arrangement. And we said crystal is a 3 D arrangement of atoms, and lattice is 3 D arrangement of points. So, the relationship between them is expressed by an equation; crystal is equal to lattice plus motif or basis. These are synonyms. You can call it motif or basis. So, this is a new concept we have now introduced. So, the linking bridge between crystal and lattice is a motif. So, what is a motif is our next topic.

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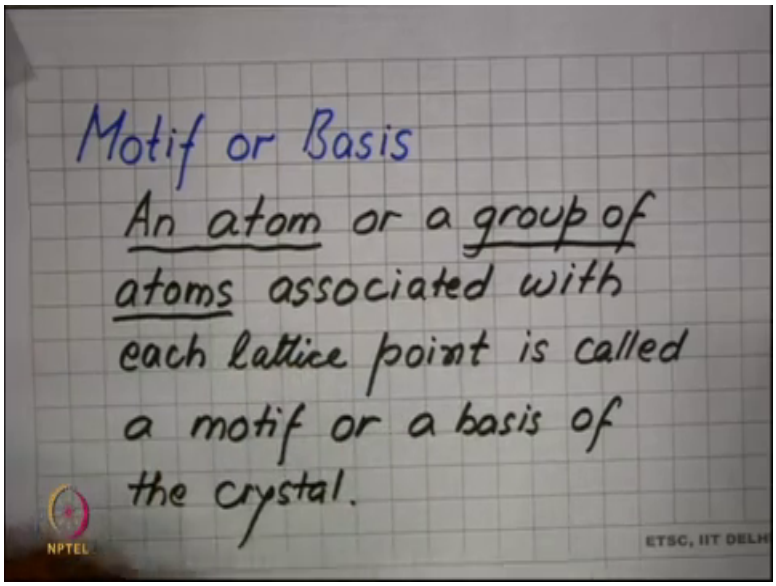

So, let us define motif or a basis. We will define it like an atom. Sometimes a motif can be a single atom or a group of atoms. So, an atom or a group of atoms associated with each lattice point is called a motif, or a basis of the crystal. So, every crystal has, from our equation, if you see crystal is equal to lattice plus motif. So, every crystal has a lattice and it has a motif. Lattice is only the periodic arrangement of points. The motif gives you the atom which is being repeated or a group of atoms. Let us make that distinction more clear.

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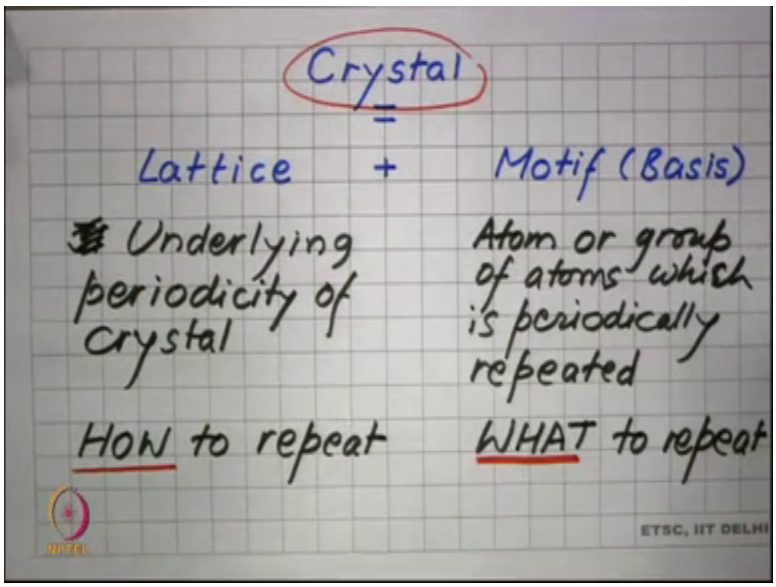

So, again lattice is a. Lattice will tell you the periodic arrangement. So, the underlying periodicity, lattice gives you underlying periodicity of crystal. Motif gives you atom or group of atom which periodically repeated, or if I put it even more simply, lattice tells you how to repeat. Lattice tells you how to repeat, whereas, motif tells you what to repeat. So, when you have both, this information how to repeat the lattice and what to repeat the motif, you get the information of the crystal, complete information of the crystal.

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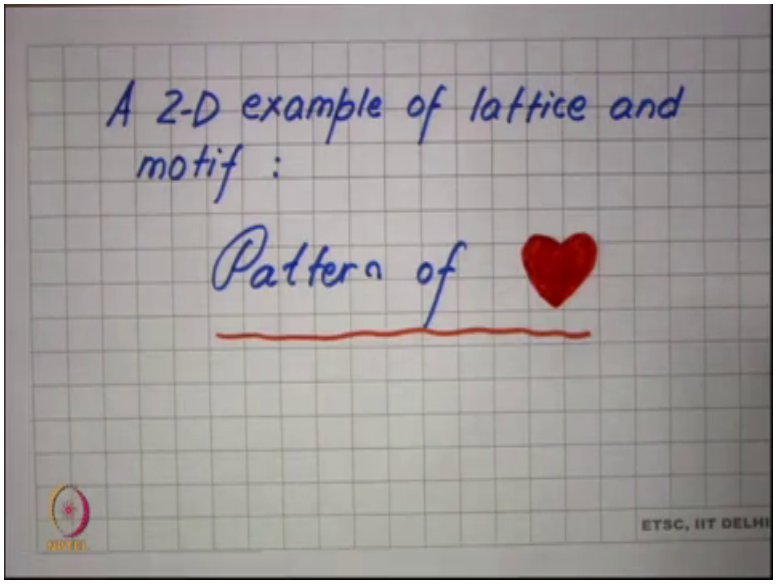

So, let us look at a little bit more concrete example, I have already shown you a 3 dimensional model of the sodium chloride crystal, but it is at the moment, a little bit more complicated to analyse. So, we will take a much simpler two dimensional example of pattern of hearts, and interesting to see a pattern of hearts. So, we come here and look at this pattern of hearts.

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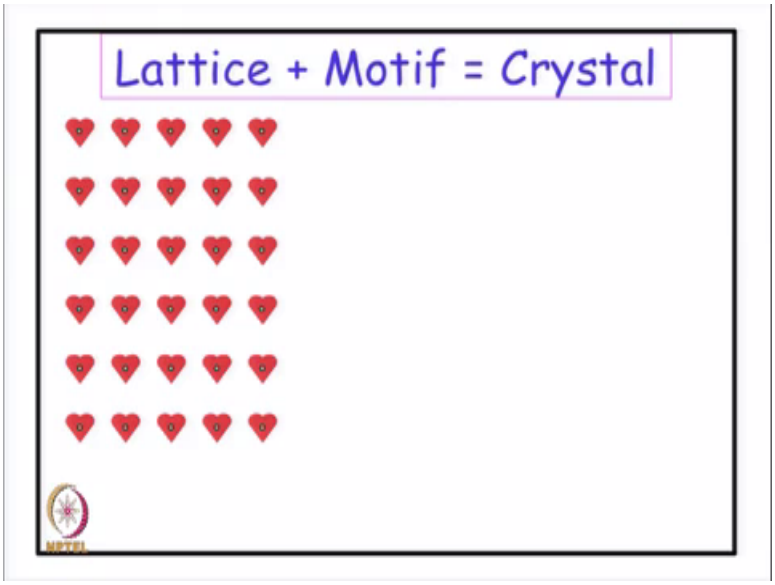

So, you can see what we are doing here, is repeating the hearts periodically in 2 dimensional. So, horizontally hearts are coming at equal distance vertically, also they are going at equal distance. So, we finally, end up with a 2 dimensional periodic pattern of heart I want to analysis. So, this periodic pattern of heart, it is something like our crystal, where atoms are repeated. Instead of atoms we are now having hearts which are repeating. So, this represents our crystal or a pattern. Now if I want to analyse it, this pattern as a lattice and motif just like crystal. Crystal is a periodic pattern of atoms. Now we have a periodic pattern of heart. This also can be analysed as lattice plus motif

So, first let us look at the lattice. So, I have now placed a dot in the centre of each of the heart. So, these dots now represent the lattice of this pattern. So, if I remove the heart and only leave the these points, this gives me the lattice of the heart pattern,

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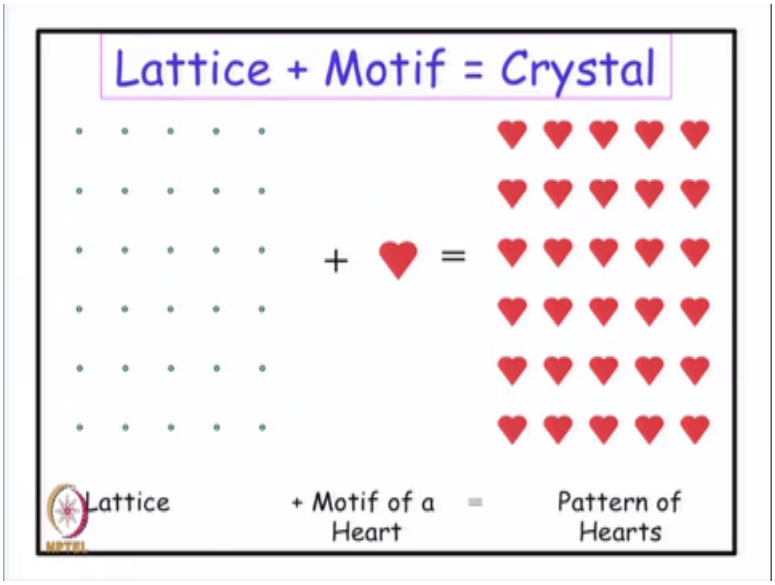

But this is not the pattern you can see, but this is associated with the pattern, and this is telling me how the heart should be repeated. I should place a one heart at each of these points in identical orientation to get my full pattern. So, I need this information that what I want to repeat instead of heart or instead of a red heart. I could have repeated a black heart and would have got a different pattern, or I could have repeated a circle and it still got a different pattern.

So, the lattice itself does not tell you what pattern you will generate to get the information about the pattern. The real pattern you need to know what is being repeated by this scheme of lattice and that information is contained in the motif here. So, this is the motif which is of this pattern. If we put these together, if I start associating one heart with each of the lattice point, I generate the pattern of heart which is the final pattern. So, this pattern is decomposed or analyzed in terms of a lattice, which tells me how to repeat and a heart which is telling me what to repeat. The same process can be done for three dimensional crystals which we will do as we progress in this course.