Introduction to Materials Science and Engineering
Prof. Rajesh Prasad
Department of Applied Mechanics
Indian Institute of Technology, Delhi

Lecture - 04
Classification of lattices

Hello we have defined till now crystal as periodic arrangement of atoms and lattice as periodic set of points. In this video we will look at the classification of lattices.

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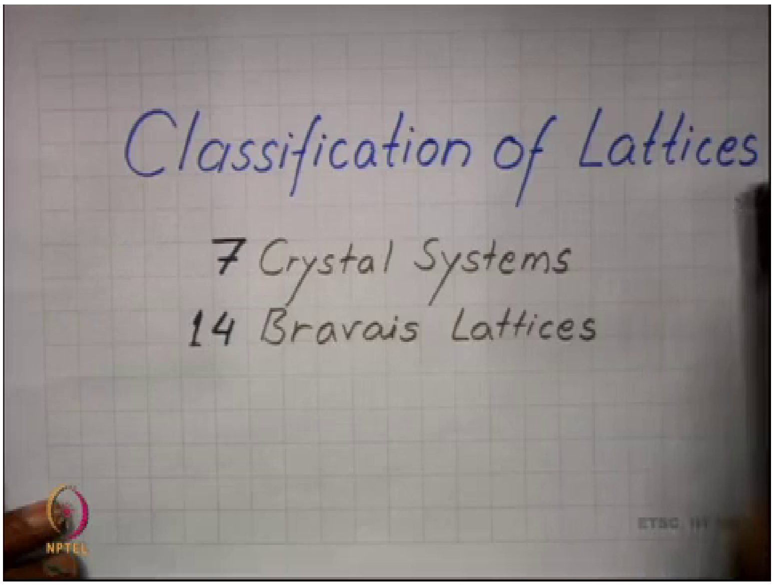

Lattices are periodic sort of points and the periodicity can vary in the 3 directions of a space. So, the axis and the angles of the crystal can have many different values. So, it is important to have a system to of classification of these lattices; 2 important systems are in common 7 crystal systems 1 of them classifies the crystal into crystal systems 7 crystal systems and another one into 14 Bravais lattices.

So, let us let us look at them here is the list of 7 crystal systems.

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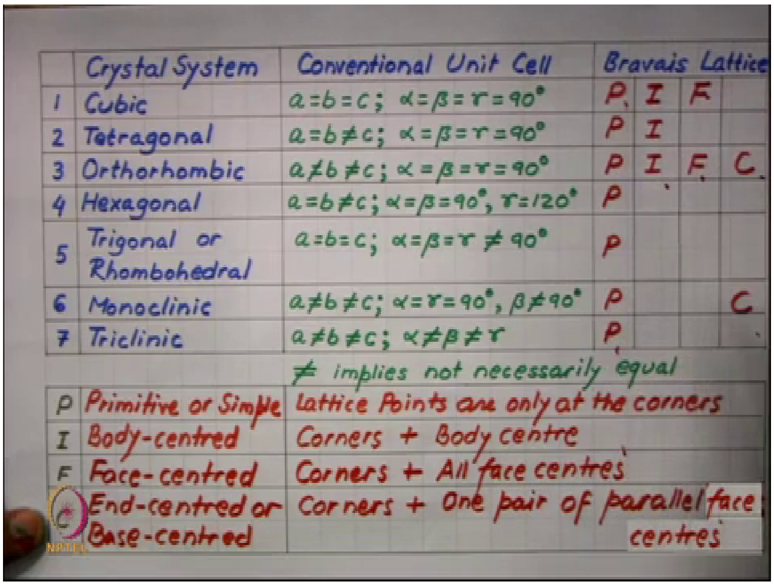

	Crystal System	Conventional Unit Cell	Bravais Lattice			
1	Cubic	$a=b=c$; $\alpha=\beta=\gamma=90°$	P	I	F	
2	Tetragonal	$a=b\neq c$; $\alpha=\beta=\gamma=90°$	P	I		
3	Orthorhombic	$a\neq b\neq c$; $\alpha=\beta=\gamma=90°$	P	I	F	C
4	Hexagonal	$a=b\neq c$; $\alpha=\beta=90°$, $\gamma=120°$	P			
5	Trigonal or Rhombohedral	$a=b=c$; $\alpha=\beta=\gamma\neq 90°$	P			
6	Monoclinic	$a\neq b\neq c$; $\alpha=\gamma=90°$, $\beta\neq 90°$	P			C
7	Triclinic	$a\neq b\neq c$; $\alpha\neq\beta\neq\gamma$	P			
		$\neq$ implies not necessarily equal				
P	Primitive or Simple	Lattice Points are only at the corners				
I	Body-centred	Corners + Body centre				
F	Face-centred	Corners + All face centres				
C	End-centred or Base-centred	Corners + One pair of parallel face centres				

We have cubic Tetragonal, Orthorhombic, Hexagonal, Trigonal or Rhombohedral. So, there are 2 alternative names for the same system Monoclinic and Triclinic. Each of these systems have a conventional unit cell which we have shown here. So, in the cubic system you have a unit cell in which all sides are equal a equal b equals c all angles are equal alpha equal beta equal gamma and all these equal angles are equal to 90 degree.

So, basically you have a cube as your unit cell and that unit cell is repeated in a space to generate the entire lattice tetragonal lat lattice tetragonal cubic system has a unit cell conventional unit cell, which is almost like cube all angles are equal to ninety degree 2 sides are equal, but third side is not equal orthorhombic also all axis are mutually orthogonal or angles are 90 degree, but none of the 3 sides are equal similar relationships are given here for all other systems you do not really have to worry about memorizing all this in one go, but gradually you will become familiar and in case if you need sometimes and you do not remember you can always look it up in some book , but let us try to understand the meaning of the crystal system and Bravais lattices.

So, 7 crystal systems we have 14 Bravais lattices in each crystal system there are 1 or more Bravais lattices P which is stands for primitive or simple is present in all of them. So, we have 7 primitive or simple lattices one each in the 7 systems. So, P is stands for primitive or simple and which means lattice points are only at the corners of the unit cell.

The next type is I or body centred body centred which means lattice points are at corners as well as the Body centre, this Bravais lattice is presenting cubic tetragonal and orthorhombic.

We now have 7 plus 3 10 4 more Bravais lattices are they F stands for Face-centred face centred which means lattice points are at corners; corners will always have lattice points whether in simple or body centred or face centred corners plus all face centres F is there you have cubic F and you have orthorhombic F. So, 2 F lattices are they finally, C is called either End-centred or it has an alternative name also base centred in centred or base centred here the lattice points are at corners and not on all faces as in face centred, but only on 1 pair 1 pair of parallel faces the C centred or end centred lattices are there in orthorhombic and in monoclinic.

So, we have now 7 7 P 3 I is 10 2 F 12 and 2 C 14. So, this constitutes the 14 Bravais lattices let us familiarize ourselves a little bit more with the Bravais lattices.

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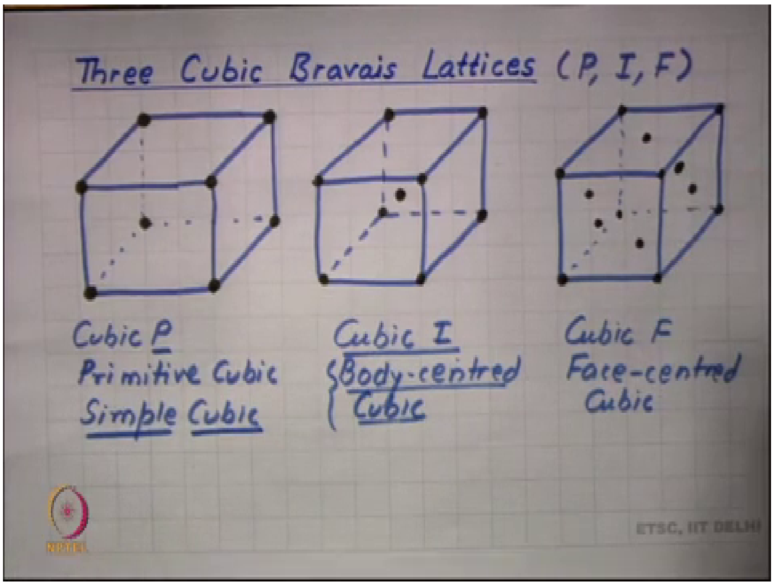

So, let us look at the 3 cubic Bravais lattices in the cubic system we said we have P we have I and we have F. So, what do they look like this is my cubic unit cell and when I say cubic P or primitive cubic or simple cubic more common name is simple cubic?

So, the Bravais lattice name includes the crystal system name as well as either the symbol cubic P or in language we can say simple cubic and the simple cubic lattice will have the simple means the lattice points are only at the corners. So, only corners are identified as lattice points do not think of these as atoms they are only points I am highlighting them to emphasize that the lattice points are only at the corners.

Let us draw the next one let us drop cubic I this will be body centred cubic both names are synonymous or equivalent. So, you can say cubic I or you can say body centred cubic here the lattice points will be at the corners as I said corners will always be lattice points, but there will be an additional lattice point right in the centre of the cube.

So, this will be the body centred cubic lattice and finally, let us try to draw the face centred one that is the cube as usual lattice points at the corner, but to qualified as cubic F or face centred cubic we have to give additional lattice point at the centres of all the faces. So, at the centre of left and right face at the centre of bottom and top face as well as at the centre of the front and the back faces. So, all 6 faces will be centred. So, then we will have a cubic F lattice. So, that is the meaning of these symbols and the location of the lattice point cubic system does not have end centred or as we said can be called base centred also, but also rhombic has.

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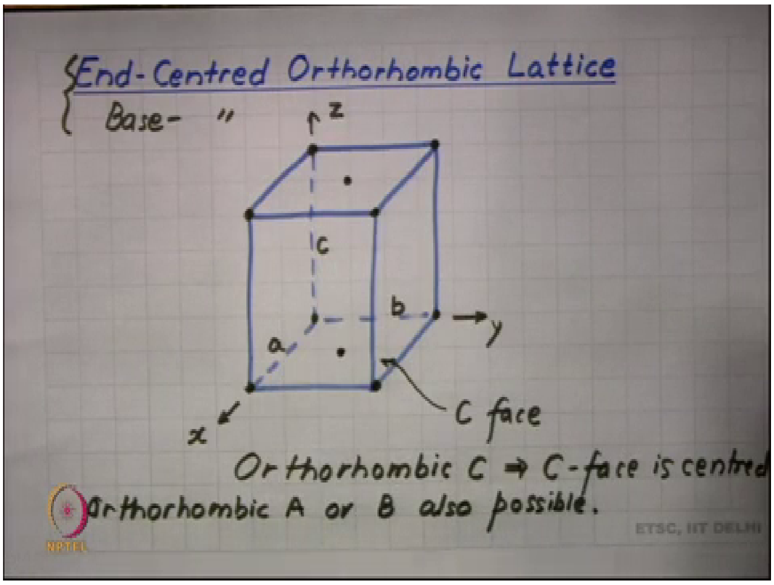

So, let us look at the example of base centred in an orthorhombic orthorhombic has all 3 sides an equal, but axes are still at 90 degree. So, that is my unit cell box and the location of lattice points at corners and to make it base centred or end centred, I have to centre one pair of opposite faces one pair of parallel faces not all faces if I centred all faces I get the face centred lattice, but if I centre let us say only the bottom and the top faces lattice points additional lattice points only on one pair of faces then I end up with end centred or base centred orthorhombic lattice it is called orthorhombic C, because if I choose my axis if I choose my axis x y and z in this way note that in crystallography the a is along the x axis b is along the y axis and c is along the z axis.

So, the face which we have centred is the face containing a and b this face is called the c face capital C face. So, when I say orthorhombic C, I mean orthorhombic c this means C face is centred of course, one can have if I had chosen to centre the other faces I can have orthorhombic a orthorhombic a or b also possible; however, since only one pair of face is centred you can always choose your z axis or the c axis perpendicular to that face and make it orthorhombic C.

So, we have we have seen we have simple.

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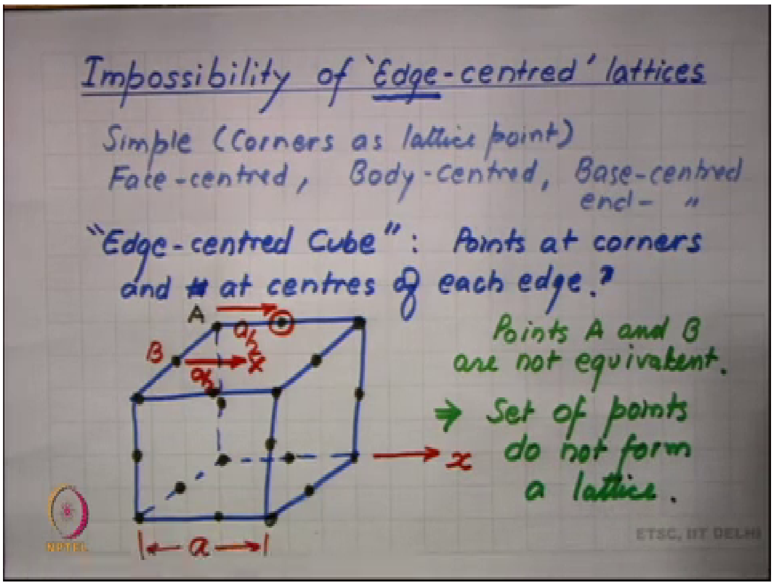

We are only corners are there corners says lattice point then we had face centred F, then we have Body-centred and we also had a base centred or end centred. So, the question can be asked why do not we have any lattice which we can call edge centred by edge centred we will mean points at the centres of each edge.

So, let us con consider edge centred cube. So, points at corners and at centres of each edge centres of each edge let me construct 1 unit cell like that again I have my cube I put points at the corners and I also put additional point at the centres of each edges the centres of each edge, why is no a lattice while is listed like this an edge centred cubic lattice or an edge centred orthorhombic lattice the answer to that can be seen by examining the surroundings of the point.

So, let us look at let us look at point A let me call this point A and let me call this point B and let me choose this direction as my x direction. So, if I move from a and let me call the Edge length of the cube as a. So, if I move from point a in the direction x at a distance a by 2 I find another neighbour this one, but if I move from point b in the same direction that is in the x direction, the same distance a by 2 I do not find any additional point. So, we conclude that points A and B are not equivalent points are not equivalent not translational equivalent. So, the set of points do not form a lattice.

So, let us again look at the complete list or Bravais lattices which we had.

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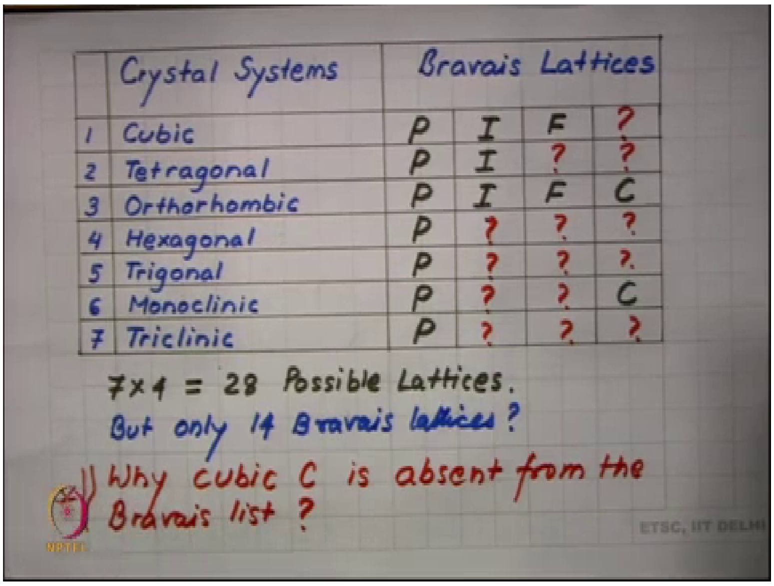

So, we were we were having cubic P simple cubic cubic I and cubic F we had tetragonal P and tetragonal I with orthorhombic P orthorhombic I orthorhombic F and orthorhombic C. So, orthorhombic is quite rich it has all the 4 varieties we have hexagonal P and that is all we have trigonal P we have monoclinic P and monoclinic C and we have triclinic P. So, we can see that 7 different lattice 7 different crystal systems are there and in each crystal system like an orthorhombic 4 possible Bravais lattices could have been there, P I F and C, but only orthorhombic has all 4. So, 7 systems 4 types 7 into 4 28 lattices were

Possible Lattices, but we have only 14, but only 14 Bravais lattices. So, why so many other lattices which were possible, but are not there in particular, why do not we have cubic C, why cubic C with is absent from the Bravais list.

Of course, similar question can be asked for all other empty boxes why is tetragonal left not there why tetragonal C naught there and so on. So, all these empty boxes is a question mark and it is this question which we will take up in the next video. So, this will be our starting point for our next video.