Mechanical Behavior of Materials-1
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Lecture - 17
Dislocations Fundamentals

Welcome back students. So now we will look into dislocations. So now that we have introduced that there has to be a dislocation, which causes deformation or basically what we have shown yet is that the original understanding or the older understanding of deformation by sharing of two planes is not possible. And therefore there must be some other way. And that other way is a dislocation.

So even before we show how the dislocation moves, let us look at what exactly is a dislocation and in the process, you would also be able to appreciate how dislocations can cause the overall slip or deformation in a material. So let us begin. Okay, so to begin with let us realize or let us introduce you to the fact that there are two different kinds of dislocations, two distinctly different types of dislocations. One of them is called edge dislocation.

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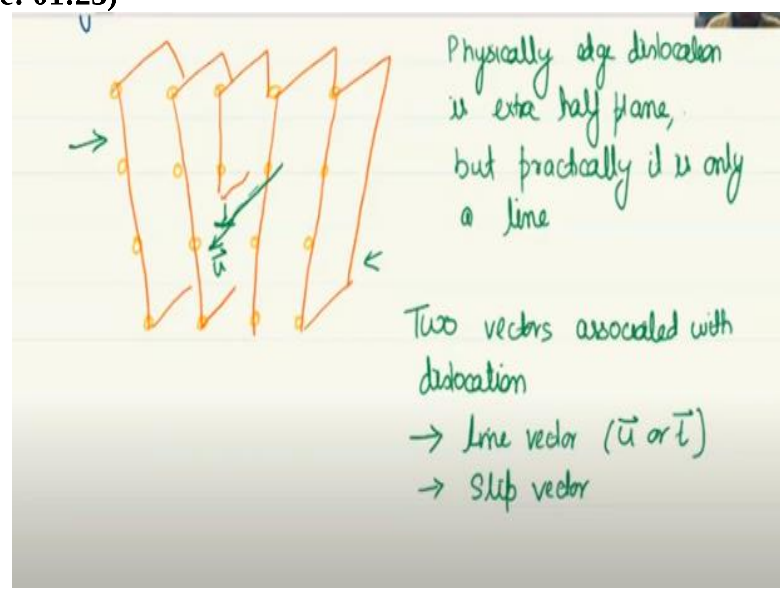

And when you take a closer look at edge dislocations you would realize on its own how it would make deformation easier and why theoretical strength of the material is not needed for deforming the material. So let us say that we have atoms, so let me use a different color. So we are looking at a single crystal from one side one edge, meaning this is this whole thing is a plane.

So this is a plane like this and this is a half plane. So this is a 3D structure although I have shown only a 2D view of it, when we are looking at atoms, but now that I have drawn the planes it will be clear to you that it is a 3D structure. So these are rows of atoms. When I draw that one circle it is representing row of an atom.

And clearly you can see that this particular row of atom, sorry this particular column of atom ends abruptly somewhere over here and it does not go all the way over here unlike the other ones. So for these there is continuity. This is whole plane, this is whole plane, this is whole plane. On the other hand, this is just half plane. So edge dislocation is basically also you can define it as extra half plane.

So physically is extra half plane. However, if you go further away from this particular line, so this is our, this is usually represented by this inverted T and this would be extending all the way over here. So if you go away from here, it is a perfect crystal. You go any direction you would see it is a perfect crystal. So the trace of this dislocation is obtained along one line.

And therefore, if you remember when I was introducing you to the dislocations I said that in TEM it appears as single lines, dark lines, and it is because of this. Because the trace of this dislocation is nothing but a line and therefore, although physically edge dislocation is extra half plane, but practically it is only a line.

And if you were to look at this in TEM, this is the line that would actually appear in your TEM images, because the rest of it is a perfect crystal and only this line is what is imperfect, which gets reflected in TEM. Now when we have n edge dislocation, we have this line. Now this is what we understand. This is the line practically. So now this line has two distinct vectors associated with it.

So what are these two vectors? One is the line vector. So if you take a tangent at any point then that becomes the tangent or the line vector for this. So this is called a line vector and usually represented as u or sometimes also as T. Another vector that is associated with dislocation is what is called a slip vector. Now at this point let me introduce you how this dislocation moves.

So this dislocation moves by moving or hopping from one plane to another. So this line, this is extra half plane for now. But these whole layer of atom would now move on to or get associated with these atoms. And therefore, this will become extra half plane. Then if you keep and you are applying stress like this, so this one moves over here and this becomes extra half plane. Then this again gets joined to this and this becomes extra half plane.
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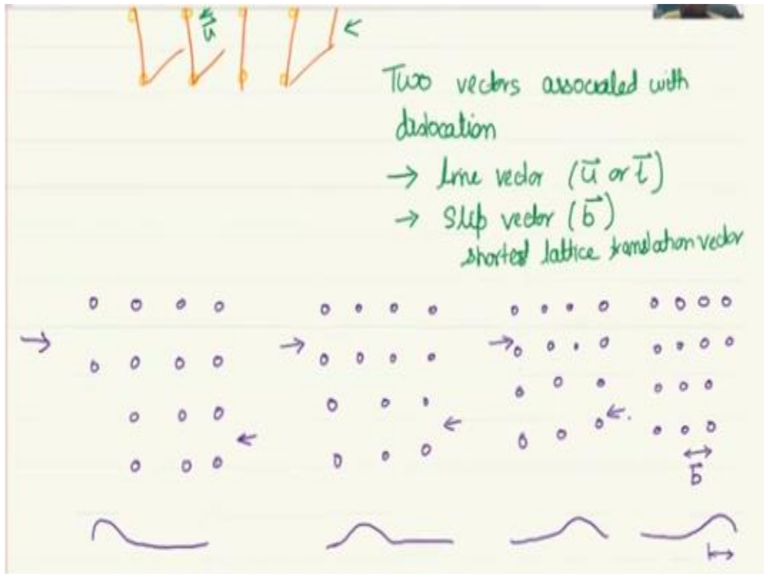

Or if I were to draw it then it would look like, so let us say you are applying stress, shear stress to make it simple or to make it clear. So this is how it would look like in the beginning. Then when you have applied stress, so this layer of atom now gets bonded to this one and this becomes the unbonded layer. And these two remain same as before.

But since you keep applying the stress, so this will hop again from now this will get bonded to these layers. And again remember when I show you one atom it is actually a row of atom. And if you keep applying this, what will happen is that this extra half layer will move on to the surface. So assuming that we have reached the surface and this when you have more and more of such steps, this is what we saw as visual proof of dislocation.

This can be visualized in optical micrograph, in SEM or sometimes even with naked eyes. And this kind of movement is also termed as caterpillar movement or it has been equated with a caterpillar movement. So it is like, this is the caterpillar. It makes a bump over here. Then this bump moves ahead, then again this bumps move further ahead and eventually the whole caterpillar has shifted by small distance.

And this is small distance is equal to the step size or the distance between the atom, the smallest distance between the atoms. And this is what is called as slip vector. So this will become our what is also termed as b. This is equivalent to shortest lattice translation vector. It will not be preferred along a direction where that it is not the shortest. For example, it will not like to move along this.

It will like to move along the shortest lattice translation vector. So this is edge dislocation and we see that it is associated or it has associated with it two different vectors, line vector, which is the tangent of the line and the slip vector which defines the direction along which this particular edge dislocation moves.

Now this slip vector is actually defining not the direction in which the dislocation is moving, as you would see with respect to screw dislocation, but it defines the direction in which the overall slip is taking place in the material. So here you can see this is over here that is slip vector is along this direction and this is the direction along which this whole step has formed. So this is about the edge dislocation.

But similar to it, we have one more important aspect about the edge dislocation, which is how to obtain whether there is a dislocation existing in a material or not. And if it is existing, what is the magnitude of the Burgers vector over there. So for that what we need is called the Burgers circuit.
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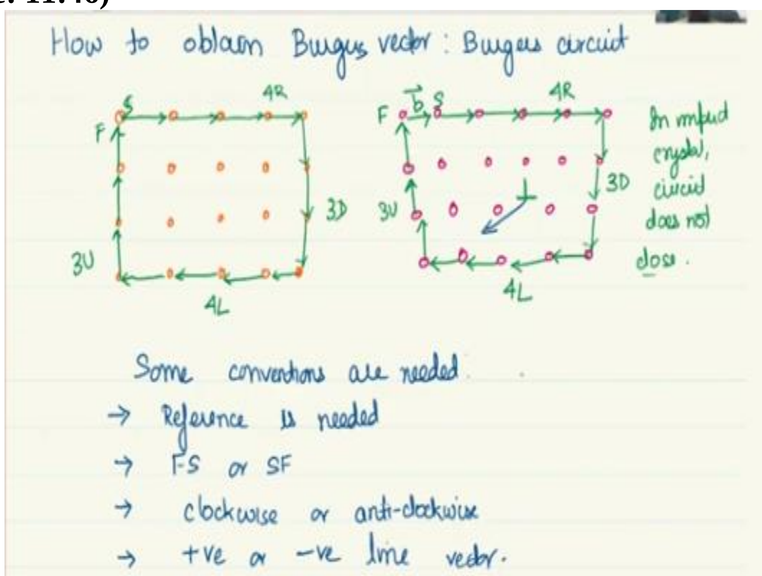

And Burgers because it is named after a person Burgers, so it is always to be written in capital B and ends with s. So what we need is a Burgers circuit. So how does this Burgers circuit work? Let us say we have again we are looking at atoms from one edge. So first we will compare or look at a perfect crystal and then we will draw the schematic of distribution of atoms in a crystal containing dislocation.

Because when you want to obtain the Burgers vector you need to compare it with a reference circuit with the reference circuit is obtained on a perfect crystal. So here I will draw, I will change the color a little bit. So here let us say we draw a circuit. So the circuit is to be drawn. So if we are going let us say four steps right, so this is 4 right. Then we move let us say 3 left, sorry 3 down.

And then since we went 4 right, so we will now move 4 left along these shortest lattice directions, along this shortest lattice vectors. Then we will go 3 up. Now if it were a perfect crystal, what will happen?

So this is start and this is finish. So start and finish would happen at the same place. Now let us do it do the same thing when the crystal is not perfect. So let us go. So this time we will just go 3 steps to the right 3 steps to the down. Here I have selected 3 right because I have drawn lesser number of atoms. Okay to ensure that there is no confusion, let me draw one extra layer of atoms because we want to compare.

So I do not want you to get confused. So we will keep with our 4 right. Now 3 down just like in the perfect crystal and then 4 left and then 3 up. What we see is that if it is imperfect crystal then this does not closes. And this gives us the hint that there is a dislocation. And if the dislocation is here then based on the circuit we can identify what is the Burgers vector. So here this is the start, this is the finish.

And now we will need a little bit of convention. What is that convention? So there are some things we need to establish before we say whether the vector is like this or like this. What are those things that we need to describe?

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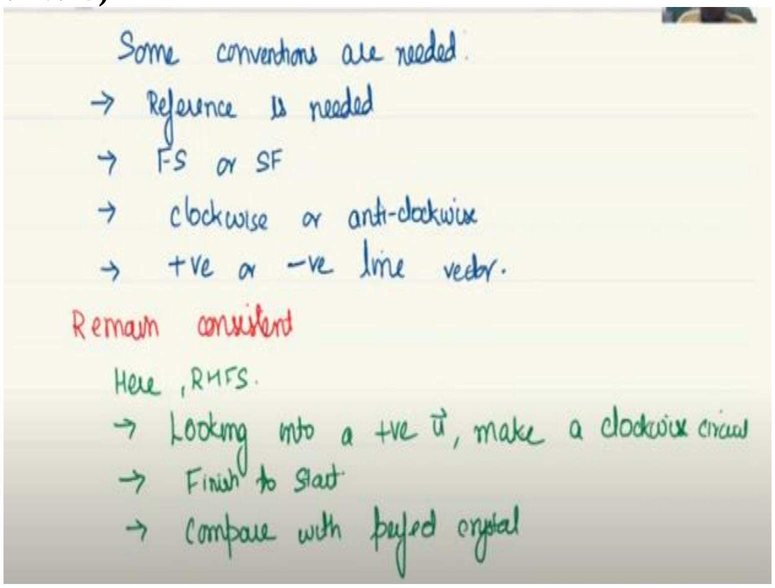

So some conventions are needed. One a reference is needed. So we are doing it with respect to this reference. Then we need to establish whether we want to go finish to start or start to finish. So you have to have this convention and you will have to stick with that convention for a given system. Then you have to establish whether you want to go clockwise or you want to go anti-clockwise for the circuit.

Then there is also this line vector that is coming out from here. So whether we are drawing with respect to the positive line vector looking into the positive line vector or looking into the negative side of the line vector. So we have to describe positive or negative line direction. So you have drawn this circuit along which for example, here I would say that a clockwise circuit has been drawn while looking into the positive line vector.

And one will have to remain consistent. So in this particular case we will, here we will follow what is called as RHFS. So RHFS means right hand. So what we mean by right hand is that looking into a positive line direction make a clockwise circuit. Finish to start that stands for FS. And compare with perfect crystal. So based on this you can see that we have over here finish to start.

And therefore here this vector would be this one. This would be defined as the Burgers vector for this edge dislocation. Now you will have to ask yourself whether I would get the same Burgers vector if I had defined the line vector in the opposite direction. And the answer would be no, you would get a different Burgers vector. So the Burgers vector definition is dependent upon the line vector that you have defined, how you define the line vector. So in that sense the positive and negative edge dislocations are physically same.

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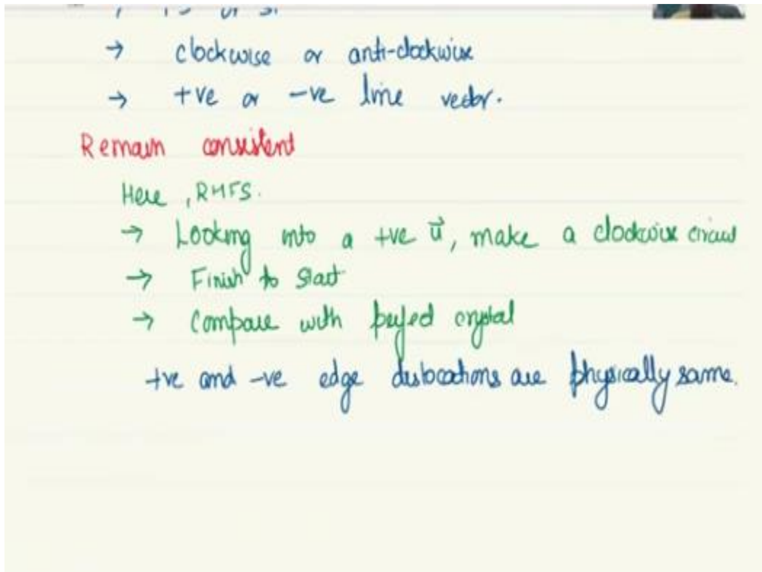

Now let us move on to another dislocation which we mentioned earlier is which is a screw dislocation.

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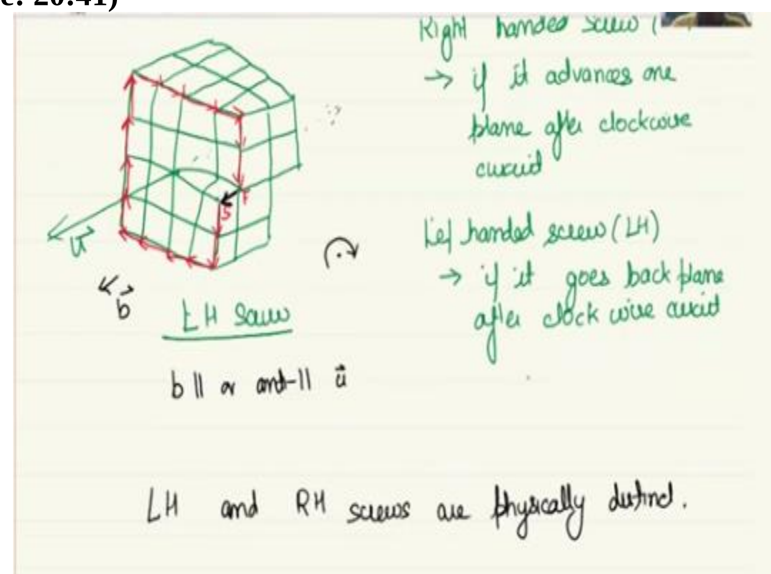

It is named screw because if you look at it, it has a helical type of structure which gives it a characteristics of a screw. So for example, let me try to draw it here. It is not so easy to draw it here but let us see. So this represents a screw dislocation and you can see that why it is true because it has a helical structure. It is rotated like a or it has been turned from here over here.

So this becomes your line vector and if you go along this line you would see that all the atoms are actually arranged helically over along this line. If you go inside this line all atoms would have been arranged helically. So they all would be shifted just a little bit and away from the plane. Almost they would be at the same position but they would be shifted along this direction by a small amount and which gives it the helical form.

And over here this would become your line vector and if we again we need to establish certain conventions here also. So here what we have is right handed screw or left handed screw. Right handed screw are ones where if it advances one plane after clockwise circuit. The other one would be left handed if it goes back one plane after clockwise circuit.

So clearly what we have here if you look at it, so here somewhere over here we will make the circuit and after one cycle you are going back one plane. So this one is a left handed screw. Okay, so based on our, what we have defined as right handed and left handed this becomes a left handed screw. Now let us try to draw a circuit over here. So what we will do is, let us say we start from here.

We go 2 down 4 left. Then again we will go 4 up. So 2 down 4 up, so we have to come back 2 down again. But before that it is 4 left so 4 right. And now we come 2 down. So we have now completed 4 up 4 down 4 left 4 right. But finish and start have not matched. And if we look at it so this is your Burgers vector for this dislocation. So here the Burgers vector is parallel to the line direction. Parallel or anti-parallel.

So in the screw dislocation, it will always be that the Burgers vector would be parallel or anti-parallel to the line vector. For example, if the line vector were going in that direction, then this whole thing would have been if you had drawn it, then the Burgers vector would have come out in the opposite direction. And therefore, Burgers vector would have been anti-parallel to the line direction.

However if you look closely, now this is your left handed screw. If the line vector were in the other direction. So the line vector was defined on that going in that direction. So let us say it was like this. Would it still be a left handed screw or right handed screw? So this is something you have to carefully think about. So now if you go over there and you try to go clockwise one direction, because you have to make a clockwise circuit, then you would see you are still come back one plane.

Because this is where the plane is ending. So you start from, let us say this one. You take a clockwise and you come back one plane. So this is still a left handed screw. Meaning no matter how you define your line vector, and no matter which direction you see, left handed screw remains a left handed screw. A right handed screw would be physically distinct.

So this is something very important to keep in mind that in edge dislocation, the two types of edge dislocation positive and negative are physically same. But in screw dislocation there are two types of dislocation which is right handed screw and left handed screw and they are physically distinct, they are not same. But the Burgers vector can of course be positive or negative. That is always there. And usually it is represented by the symbol like this.

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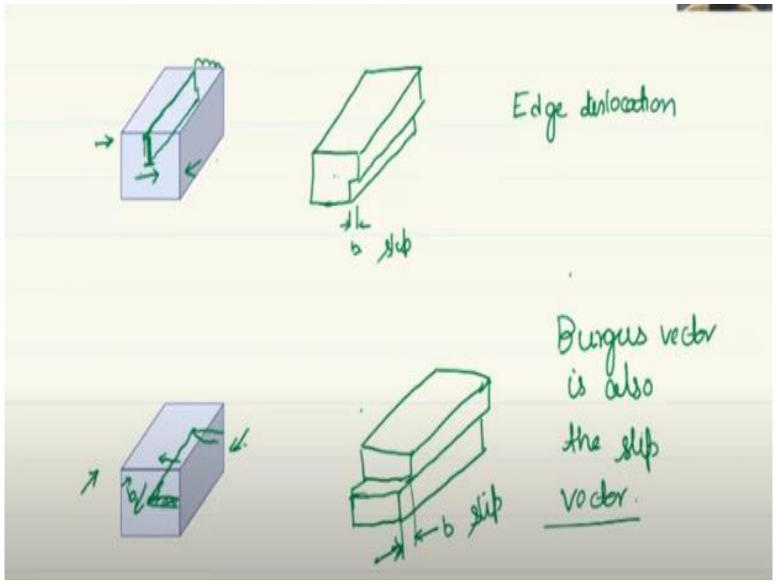

Now let us look at one last thing related to dislocation in today's lecture. And this is about slip. So we said when we were talking about dislocation, edge dislocation, that the Burgers vector also defines the direction in which the slip takes place. This is also true for the screw dislocation where the Burgers vector happens to be parallel or anti-parallel to the line distribution.

So first let us take a look at, let us say we have an edge dislocation somewhere over here. And let us say this is the extra half plane. And we are applying stress, shear stress like this and the Burgers vector happens to be like this. So what will happen to the dislocation extra half plane? It will hop from here to here to here. And eventually what you would see is that there will be a step forming along this direction.

So let me refine my drawing a little bit. This is how it will look like. And a step equal to Burgers vector has been formed over here. So this is in the case of edge dislocation. In the case of a screw dislocation, so you will have probably a slip. If you have a edge dislocation like this so there is a slip like this and the Burgers vector is probably something like this. It is either this way or the other way.

So here also you will have step like this. Now in this case you will have to be applying stresses like this and when you are applying stresses like this what will happen is that this line this location would keep moving in this direction. And with that this edge would keep on increasing and eventually what you would have is a structure like this. So here this is where the Burgers vector slip has taken place.

And here this is the Burgers vector equal to the Burgers vector and where the slip has taken place. So what it tells us is that Burgers vector also defines the slip vector. It tells us which direction the overall slip in the material is taking place. And therefore again it has a very useful significance with respect to deformation in the material. Now let us understand or summarize this with respect to the Burgers vector.

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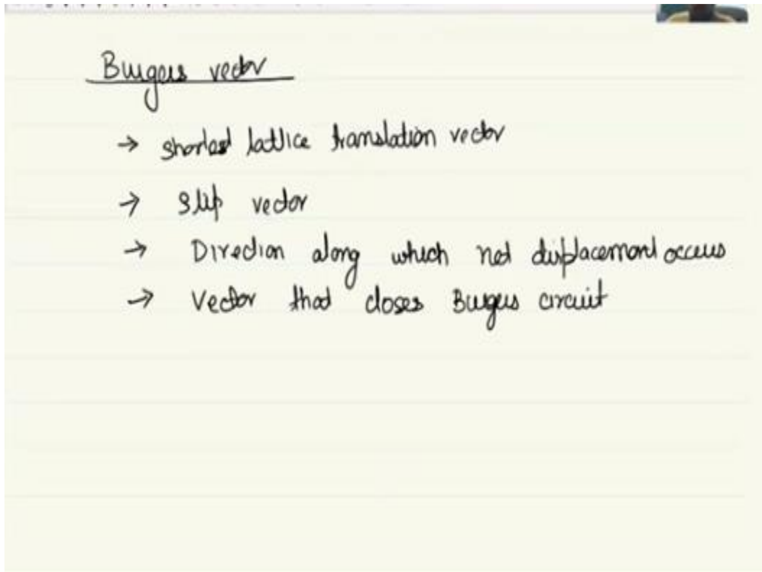

So what we have realized is that Burgers vector is the shortest lattice translation vector. It is the slip vector which we just saw. It is the direction along which net displacement occurs. It is also the vector that closes the Burgers circuit. Okay, so this is the very basics of dislocation, the edge dislocation and screw dislocation.

And when we looked at edge dislocation we also realized how it will help or reduce the overall theoretical strength because now the overall slip would take place in small steps instead of shearing all together in one go. And that is how the dislocation is able to reduce the overall strength of the material and accommodate the deformation in the material.

And when we have a dislocation we have two vectors, the line vector and the Burgers vector. So Burgers vector we saw how you can identify with the help of Burgers circuit and these are some other characteristics of the Burgers vector. So since this is the shortest lattice translation vector, you should try to find out what will be the

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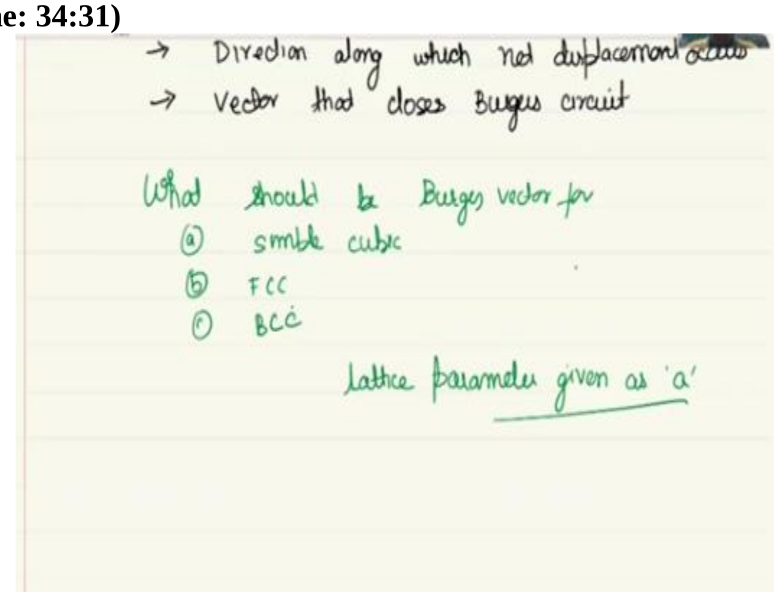

So I will leave you with this kind of home activity that you should try to do it on your own. What should be Burgers vector for let us say, simple cubic FCC, BCC where probably you have given lattice vector as a, lattice parameter not the lattice vector, lattice parameter given as a. So try it out on your own and with that we will end this lecture and we will come back and learn some more important characteristics about dislocations. Thank you.