3D Space Groups V: Glides in 3D
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Lecture 23 a

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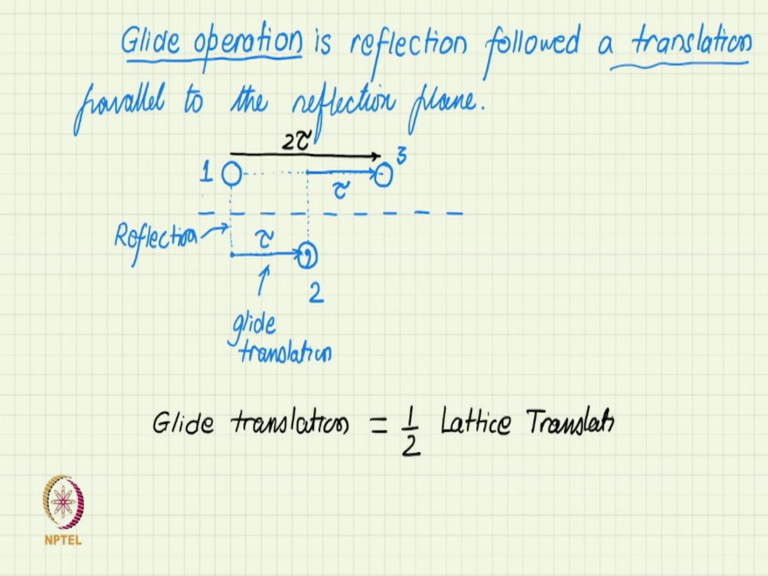

In this video, we will discuss glides in 3 dimensions. So, we have met glide in 2D when we were discussing plane group, but now, we will extend the idea to 3 dimension. So, first let us review the concept of glide. So, a glide operation by definition is reflection followed by a translation parallel to the reflection plane. So, let us try to draw a plane and an object which is although I have drawn I am drawing it as a circle as per internal International Convention, this is an object of a given handedness then I reflect it, but at the reflection point I do not put any object because the process has to follow by a translation parallel to the reflection plane.

So, I translate it parallel to the reflection plane let us say here. Now, since it is a reflected object, it will change handedness, I am showing that by changing handedness. And so, this mapping from 1 if I call it object one mapping from object 1 to 2, which involves both this reflection and this glide translation. So, combination of this operation is a glide operation, you can see that if I just reflect there is no object there. So, the reflection part is not a symmetry operation.

Similarly, if I just translate by this amount again there is no object there. So, the translation is also not a symmetry operation, it is only the combination of reflection and glide translation, which is a symmetry operation, but any symmetry operation can be applied many times. So, let me call this translation let me represent this translation as glide translation as 2. So, I if I again apply the glide operation to object 2, then I will again reflect. So, it will get back to the original handedness and I will again translate by the same amount 2 to get to 3.

So, the comma I had put for showing the change in handedness for object 2 but now, again a change in handedness of that will bring it to the same handedness as the object original object 11. So, 1 and 3 have the same handedness. So, 1 and 3 have the same handedness and this translation again is tau, because I applied the same glide operation, so, you can see that the net translation now is by 2 tau and since there is no change in handedness, there is no reflection involved here. So, this to tau has to be a lattice translation because you know objectives simply translated and repeated from 1 to 3.

So, if we note that so, the glide translation is half of lattice translation in the direction of glide. So, this is an important result. Now, let us in the we had met this as I told you, we have made this in 2D also.

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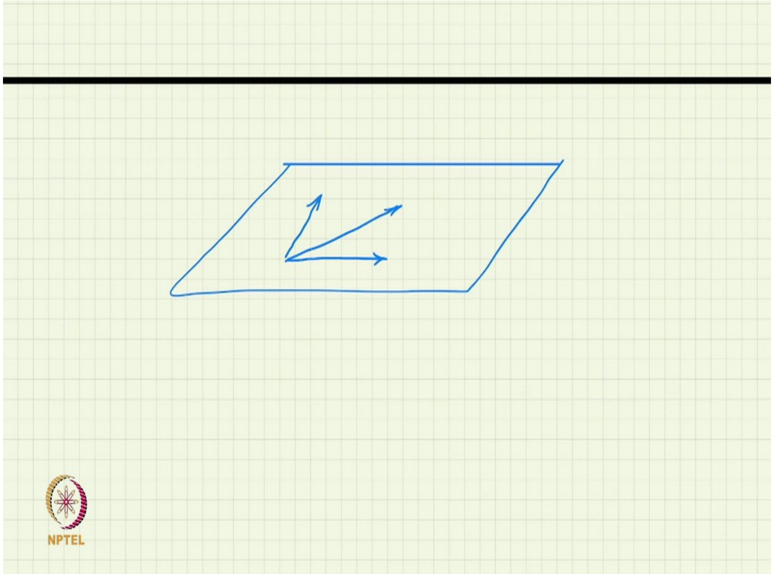

So, there it is a glide line and we have a glide operation in 3d, since we have actually a plane we actually have a plane in which glide happens. So, reflection is okay. But the translation can be in many directions, there are many possible directions of translation in the plane. So, based on this glide operations have been characterized in international table and 4 categories have been developed. So, let us look at the details of those category.

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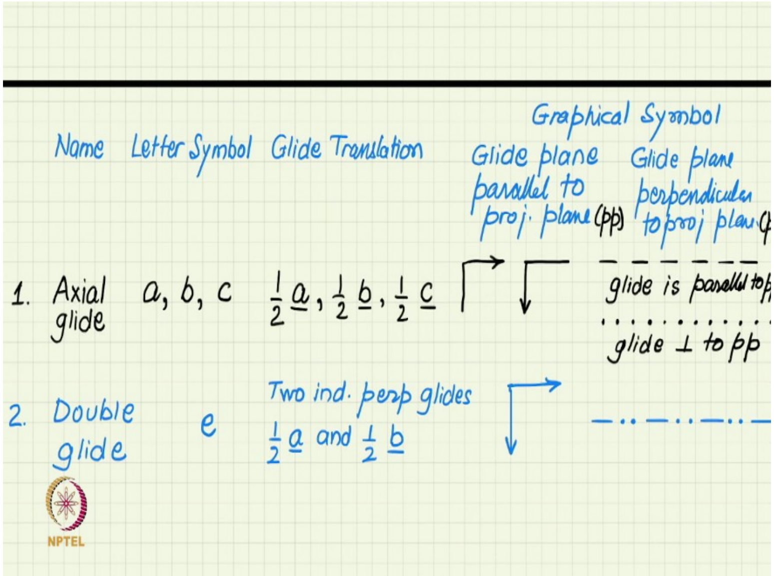

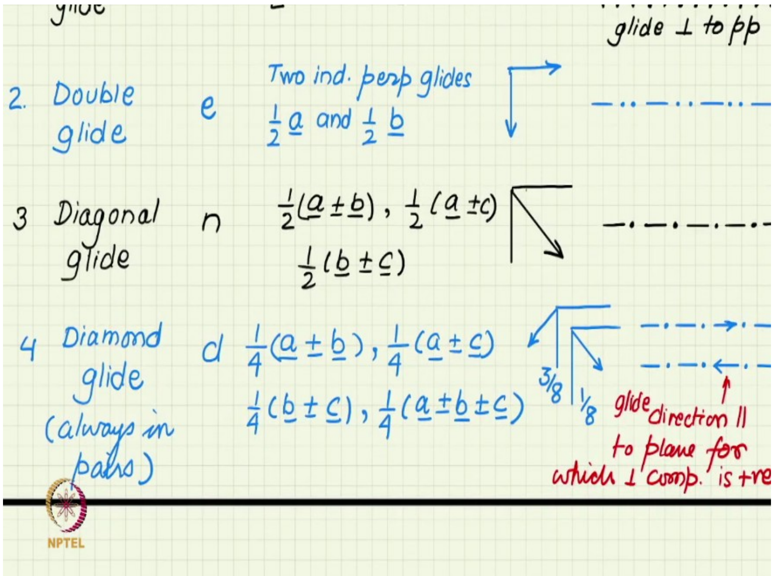

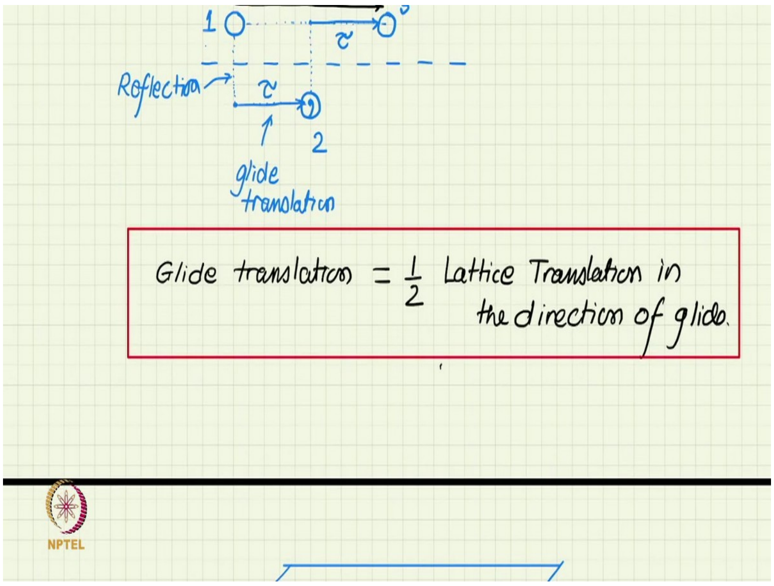

So, let me present it in a tabular form. So, I have the name of glide operation, then I will put the letter symbol that is how they come in the name of space group. So, that letter symbol in the name of a space group will represent the presence of that particular glide and then, let me write the glide translation, that is the corresponding translation vector. And then 2 kinds of symbols are used graphical symbols letter symbol is there already there, but graphical there is also graphical symbol and for every glide operation, there are 2 kinds of graphical symbol based on whether the glide plane is parallel to the projection plane glide plane, parallel to projection plane and another symbol is for glide plane perpendicular to projection plane we will look at all these.

So, let us begin with first type, which is called axial glide. So, the name is axial glide, which means that the glide translation is along one of the crystallographic axes, one of the crystallographic axes a, b or c. So, based on that the symbols given are also a, b, and c. So, we will call it a glide, b glide or c glide, depending on whether the glide translation and we have seen that the glide translation has to be half of the lattice translation. So, half a, half b, and half c. In the series of video I find that I have changed my notation of vector midway.

So, do not be confused with that. Previously, I have been using a bar above the letter to represent vector, but now I am using a bar below the letter to represent the vector. So, we have axial glide and the glide translation we have seen that the glide translation is half of the lattice translation, and we know that the lattice vectors a, b and c are the corresponding translations in those directions. So, half of that will be the glide translation. Now, if I want to represent this glide plane in the projection plane a parallel to the projection plane, then I have symbol the International Table recommends a symbol like this in the drawing and one of the arms has an arrow which represents the glide direction. So, depending upon which direction Glide is happening in the plane, the arrow will point in that direction.

Now, if the plane is perpendicular, then there are 2 kinds of symbol, one symbol which you are familiar with from 2D, I can show it by dashed line, which actually represents glide parallel to the projection planes, let me write pp for projection plane. So, if the glide is parallel to the projection plane and glide plane is perpendicular to the projection plane, then we will represent it with this dashed line. Another symbol is used if the glide plane is glide direction is perpendicular to the projection plane, the glide vector is now going into the plane or coming out of the plane. In that case, we use a dotted line to projection plane so, that is my that is my axial glide.

Another glide which is possible in 3D is called the double glide. So, double glide, so, double glide the symbol is e the letter symbol is e. And by double we mean that in this plane, there are 2 independent glides and they are perpendicular to each other. So, 2 independent and perpendicular glides will be there. So, for example, it can be half a and half b. So, both directions glide can happen, so, the plane is same, but the Glide is happening in both directions.

In this case. If the glide plane is parallel to the projection plane, we use this similar notation, but now since it is a double glide, we put an arrow on both the line segments and to indicate that say double glide, we use the symbol dash with double dots. Then we have diagonal glide the symbol is n. Here the direction of glide translation is, as the name suggests, is along the diagonal along the face diagonal of the unit cell.

So, it is half a plus minus b, or could be half a plus minus c, or half b plus minus c these are the diagonal vectors. For diagonal glide the translations happen in this direction, the symbol graphical symbol for a diagonal glide plane parallel to the projection plane is to use these 2 perpendicular lines, but then draw the arrow in the diagonal direction. So, this represents the diagonal glide and if the diagonal glide plane is perpendicular to the projection plane, if the diagonal glide plane is perpendicular to the projection plane, then we show it by dash dot line single dot.

So, dash with single dot is diagonal glide, dashed with double dot is double glides. So, easy to remember and finally, we have what is called the diamond glide the symbol is d. Here again, the translation vectors are along the face diagonal, but it is quarter of the face diagonal instead of half. So, it is 1 quarter a plus b, 1 quarter a plus c, 1 quarter b plus c, or even in some cases, it can be along the body diagonal 1 quarter a plus minus b plus minus c, the symbol for diagonal glide. Now, the symbol will be just like we had for diagonal glide, but we have another line with arrow pointing in the other direction because, this is to note that the diagonal diamond glides always occur in pairs. They will always be in pairs.

So, and then one plane will have diagonal glide in one direction, then the next plane will have a diagonal glide in other direction. So, these 2 planes are not at the same level. So, the level is indicated by a small number. So, as an example, I am giving you that 1 by 8 and 3 by 8 is one possibility. So, these are height along the direction… these are fraction of translation in the direction perpendicular to the projection plane. So, one is one of the members of the pair is at height 1 8th, whereas, the other one is at high 3 by 8th and they are glide are in different direction.

So, in the perpendicular case also you draw it in pair, but you also show one of the segments, some segments you make as arrows, some of the dashes have arrow. So, this is how it is distinguished from diagonal glide, in the diagonal glide, there is only dash dot, but here dash and dot with some of the dashes having the direction of arrow and that arrow is significant, because it indicates the direction in which you have to because diagonal glide has that sorry diamond glide has translation components both parallel and perpendicular to the plane and the arrow indicates the arrow indicates the direction parallel to glide directions parallel to plane for which perpendicular component is positive.

So, if you move in the parallel direction this way, then in the perpendicular direction you will be going in the upward direction and not in the downward direction. So, that is diamond glide, let us see, let me just give you sort of 3 dimensional example.

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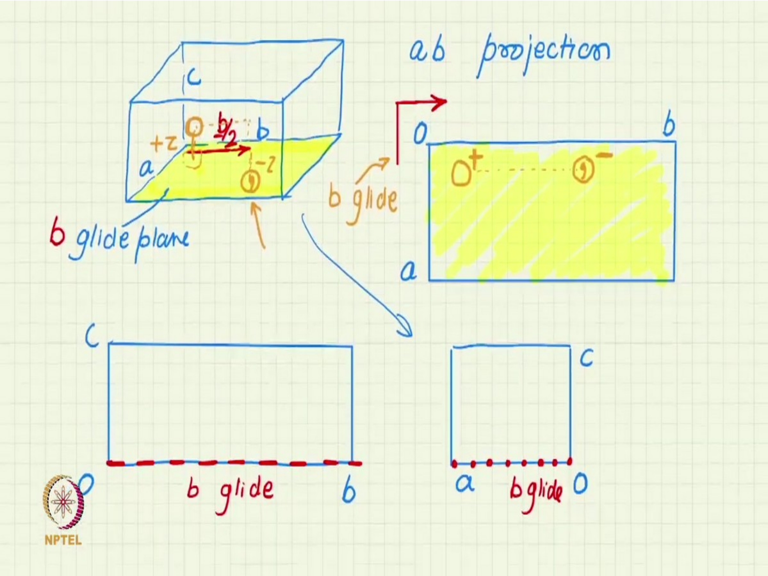

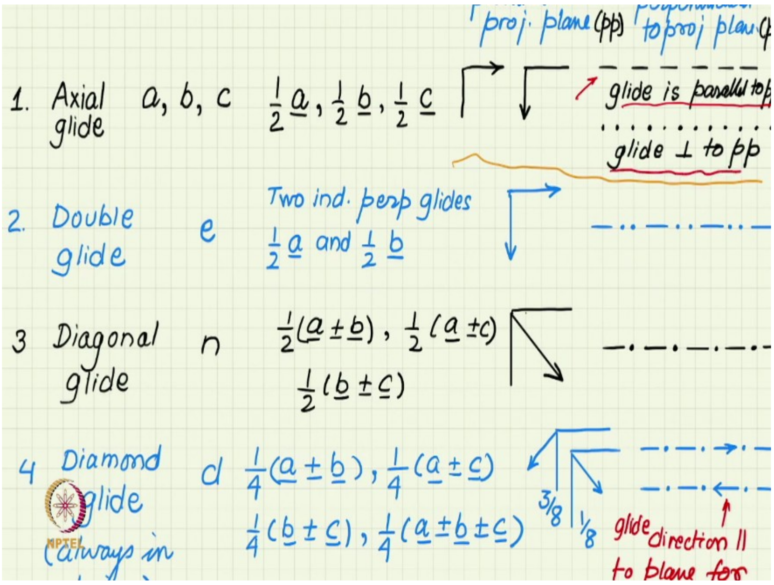

So, let me try to create and not orthorhombic looking unit cell. So, let us say that this is a, this is b and this is c and let us make for the moment this plane itself at a glide plane. So, this yellow highlighted plane is the glide plane and let us say that it is an axial glide. So, the glide vector is and it is a b glide. So, let us call it b glide. So, that means, that glide translation vector is b by 2 in that direction.

So, which means, if I have an, let us say if I have an object here in the unit cell some atom or some motive, so, it will be translated by b by 2 and then it will be reflected into the plane to go below the plane. So, if I now, let us use, so, I have an axial glide So, I can show it with the symbols in my with these symbols in my projection plane. So, let us see that how it will be represented in different projections.

So, if I have ab projection the projection plane is the glide plane itself. So, this is my glide plane and I am projecting in that plane itself. So, if I show it in this plane, then since my projection plane let us say this is a and this is b and this is the origin. So, since the projection plane itself is the glide plane, so, I will use this graphical symbol to indicate that this is a glide plane and since b direction is the glide direction, I will put an arrow here. So, this symbol will be representing b glide in this projection and of course, since I have an object there I can show it like this, but now since it is in projection, it will come on the plane there.

So, to indicate that it was above the plane, I just use the plus sign as is common in the international tables and then this has to be translated half distance of b by vector b by 2, that will come somewhere there. And then I reflect, so I am reflecting means I am now representing this particular point. So, it is change handedness, but it is now below the plane.

So, I indicated by minus. So, in fact, if this height was z, so the height is plus z. So, plus z is represented simply by a plus for economy and the same height will be represented below. So, it will become minus z, minus z is represented simply by minus. So, that is the ab projection.

What about bc projection or ac projection. So, let us create that also. So, if I now make that projection on the bc plane, how will my glide the same glide plane bc looks like. So, now, this is b this is c and this is the origin o. Now, the bc plane is not the plane of the projection. So, that symbol is not valid now, but, you can see that now the glide plane the yellow plane will project along the line b itself. So, it projects along the line and since the translation direction is lying in the plane. So, glide is parallel to the projection plane because it is in b in the direction b which is lying in the projection plane.

So, I will use I will use this dashed notation to represent it. So, let me superimposed red dashes over this line but this will now indicate the b glide again a b glide, but b glide shown in the bc projection. So, the glide plane is now perpendicular to the plane of projection, but the glide translation is still in the plane of projection. And finally, let me show you the ac projection again in this projection. So, now, this is the origin this is a this is c relating it to my diagram there. So, this is the ac projection.

Now, the glide plane will project as a line along the vector a. So, again we have the glide plane along this direction and it will be projecting as a line because now it is perpendicular to the projection plane, but the glide vector is b and the b direction in this projection is perpendicular to the plane. So, the glide direction is not lying in the projection plane, but the glide direction is lying perpendicular to the plane right direction lying perpendicular to the plane.

So, I will use this symbol that is the dotted symbol. So, all of these are representing this also b glide, this is also b glide, but they appear differently in terms of symbol in the different projections. Similar diagram you can construct for others or you can check books or international tables. We will not go into all those cases, but we may meet some of some more of them during in our future discussion. Thank you very much. We will meet in the next video.