Crystals, Symmetry and Tensors
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Lecture 8a
Definition of Symmetry

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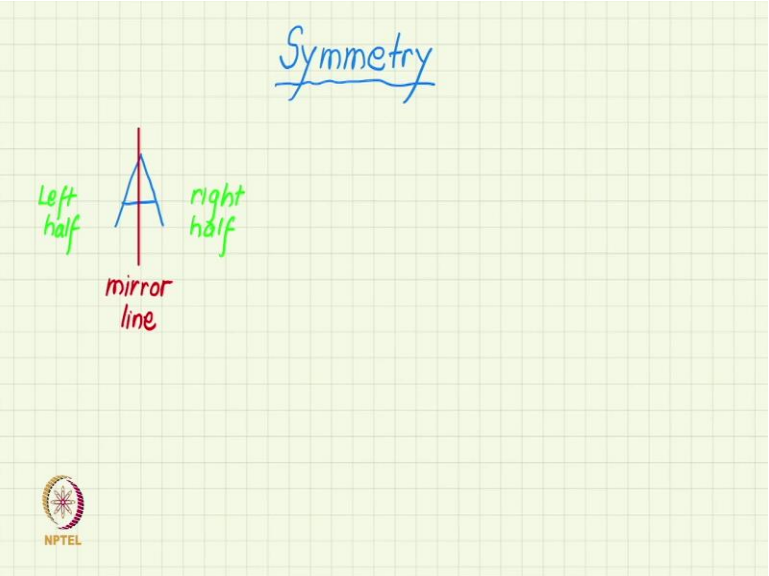

So, in this video, let us look at the concept of symmetry. So, what do we mean by symmetry? So, let us look at the English alphabet letter A. We feel that this is symmetric, because if we draw a line through the middle of the letter so, this line acts like a mirror line dividing the latter into two halves, the left half and the right half. And this is a two way mirror. So, if we reflect the left half, we get the right half and if we reflect the right half, we get the left half. So, upon reflection in this mirror line, the letter A remains unchanged. This is the basic concept of symmetry so, we can define it.

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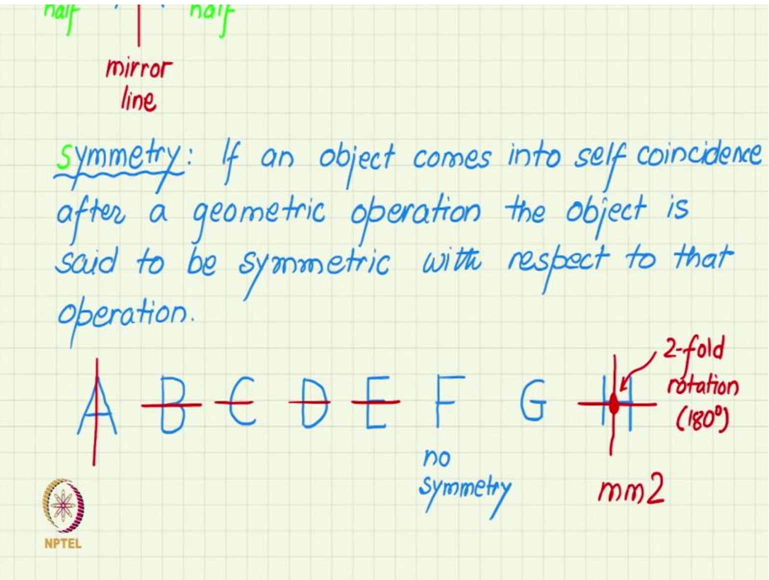

So, let us define symmetry. Let us say that if an object comes into self-coincidence, just for example, the letter A came into self-coincidence after a geometric cooperation so, in the case of letter A the geometric operation was a reflection in a line. So, if an object comes into self-coincidence after a geometric cooperation, the object is said to be symmetric with respect to that operation. So, this is a very general definition of symmetry and we have seen an example of the letter A.

Let us explore other letters of English alphabet, so letter A we have already seen has a vertical mirror. If we just look at the next letter B then that seems to have a horizontal mirror and then C, D and E all of these are horizontal mirrors, F does not have does not seem to have any symmetry. This is no symmetry. Same is the case with G.

But the next letter H seems to be highly symmetric. Because, it not only produces a horizontal mirror, it also produces a vertical mirror and we will see that if any object produces two perpendicular mirror, the line of intersection of the two mirror also becomes a center for 180-degree rotation which we call a 2-fold rotation axis.

This symmetry as we will see in this course, later is also called an mm 2 symmetry, the 2 m's represent the two perpendicular mirrors, and the 2 represents the 2-fold or 180 degree rotational symmetry about the center. So, this is an interesting exercise I have initiated you into, you can continue with the alphabet letters up to Z and see what symmetries they represent.

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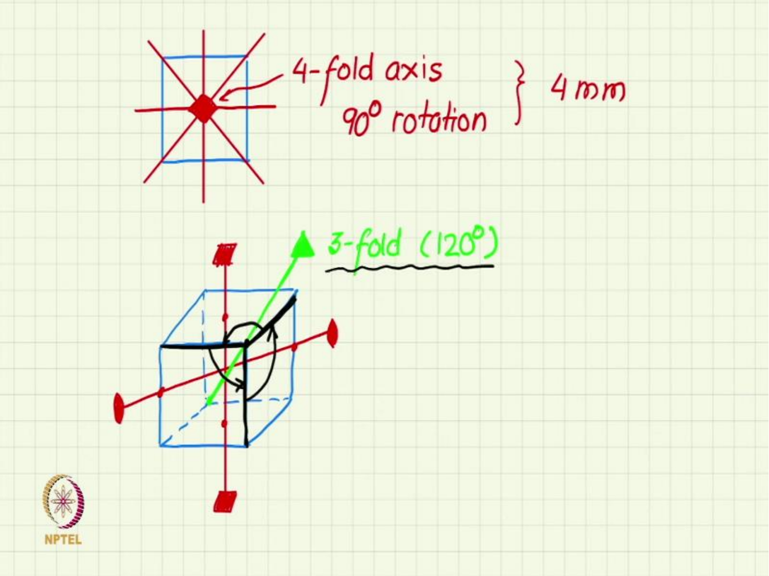

But, let us take a little bit more interesting example, now, that is of a square. Intuitively, we know that a square is highly symmetric, but by the definition of our symmetry, just like we have seen now, we see that it has a horizontal mirror and a vertical mirror just like the letter H was having, but apart from this it also has two diagonal mirrors which the letter H was not having. So, in that sense, it is even more symmetric than the letter H.

And then apart from these reflections symmetry another geometric operation, which brings it into self-coincidence is a 90 degree rotation about the center. So, that is called a 4-fold axis. You will discuss these in more detail. Here just as an example and introduction I am giving 4-fold axis which means self-coincidence after 90 degree rotation. So, in this kind of symmetry also is given a name which I just gave you here, this is called a 4 mm symmetry, 4 for the 4-fold in the center and mm represents these mirror planes.

Let us take now a 3 dimensional example. So, one of the most symmetric object in 3D is a cube. Let us look at a cube, so, cube is highly symmetric object and we will explore its symmetry in great detail later, but here you can see that it has many different kinds of rotational symmetries.

So, for example, one very obvious one is the 4-fold symmetry axis which passes through centers of a pair of opposite phases. So, you have a 4-fold axis there that is by 90-degree rotation, the cube will come into self-coincidence. It has other fourfold axis I leave that for you to work out. But there is another kind of axis you can see, which is passing through pair of opposite edges, centers of the pair of opposite edges, and this is a 2-fold symmetry, just like the one we saw in the letter H.

But interestingly, the most interesting and the defining symmetry of the cube comes from its body diagonal and which is not so immediately obvious also that this axis is actually a 3-fold axis 3-fold that is a rotation of 120 degree brings it into self-coincidence. It is not easy to see in a diagram like this, but I will still point out what you should do is to work with a model. But if you see on the body diagonal along these corners, three edges are meeting I am highlighting one set of three edges.

And if you rotate by 180 degree about this green axis, the 3-fold axis, then these edges of the cube will permute. So, one will come into other and the whole cube will come into self-coincidence. So, it is very, very interesting to note that 3-fold symmetry is also present in a cube. Thank you very much.