STUDENT: Hello. Today we are going to talk about real and reciprocal space in two dimensions and three dimensions. Crystallography is a major topic within material science. A crystal is a highly ordered solid material made up of a lattice and a periodic arrangement of atoms.

Atoms are located on every lattice site. Due to the periodic nature of the structure, all crystals display what's called translational symmetry. Crystals are defined by their lattice vectors, which are different in two dimensions and three dimensions.

In two dimensions, lattice vectors are the shortest and next to shortest translations from a given point. These lattice vectors are called a and b. Four types of general 2D lattices exist-- oblique, rectangular, square, and hexagonal.

In an oblique lattice, a and b are different. And the angle between them is greater than 90 degrees. In a rectangular lattice, a and b are different. And the angle between them is 90 degrees.

In a square lattice, a and b are the same. And the angle between them is 90 degrees. And in a hexagonal lattice, the a and b are the same. And the angle between them is 120 degrees.

On the other hand, lattices in three dimensions are defined by the three lattice vectors a, b, and c, which have angles of alpha, theta, and gamma between them. There are seven types of simple crystal systems, which you can see here. These structures range from simple cubic, where all the lattice vectors are equal and all the angles are 90 degrees to triclinic, where all the lattice vectors and angles are different.

One thing to note about this hexagonal crystal system is it's actually made up of three unit cells, which you can see here. In 3D, there are also non-simple crystal systems. With the non-simple crystal systems added, there are 14 total possible crystal structures. For example, body centered cubic and face centered cubic are non-simple cubic crystals.

Crystals exist in real space. This is the physical world around us. Unfortunately, not all concepts in materials science can be properly represented in real space. Reciprocal space is a non-physical space. In material science, it is mainly used to portray diffraction phenomena.

For those of you who know, reciprocal space is the four-year transform of real space. However, this information is not important to understand the rest of the video. Reciprocal lattice vectors relate to sets of planes in real space. Reciprocal space has some key properties that related to real space. These properties include the units of reciprocal space or an inverse length. The volume of a reciprocal unit cell is inverse of the real space volume. And the plane spacing is inverted. See the attached notebook for more information about reciprocal space and how to calculate reciprocal lattice vectors.

Consequently, a reciprocal space is a very important concept. For example, it is a key property in understanding X-ray diffraction. In X-ray diffraction, a beam of incident X-rays are diffracted in a material. And the diffraction angle is measured.

This produces an electron diffraction pattern seen here. Here the electron diffraction pattern is of silicon carbide. Points in the pattern originate from a set of planes in the crystal. And each point represents a reciprocal lattice vector. Therefore, electron diffraction patterns exist in reciprocal space.

Now we are going to compare unit cells in real and reciprocal space to better visualize the change from real to reciprocal space. As I said earlier, there are four types of 2D lattices. In this image, you can see the real space lattice. And in this image, you can see the reciprocal space lattice.

In real space, there are lattice vectors a and b. And in reciprocal space, there are lattice vectors a star and b star, which are perpendicular to their real counterpart. As you can see here, a change in real space produces an inverse result in reciprocal space. As the real unit cell shrinks or expands, the reciprocal unit cell does the opposite. The same holds true as the angles change.

In three dimensions, it is a little more complicated. As I said before, there are seven types of simple crystal systems. This image is the real space unit cell. And this image is the reciprocal space unit cell.

Similar to two dimensions, the real lattice vectors are a, b, and c. And the reciprocal lattice vectors are a star, b star, and c star. The points at the vertices represents atoms in the simple unit cell.

As you can see, as I change the size of the real unit cell, the volume between the two cells move in opposite directions. As the lattice vectors change, the change in shape and volume of the unit cells are clearly different. For the simplest example in cubic, if we shrink the unit cell in real space, it expands in reciprocal space. You can see this kind of behavior in any of the unit cells.

Hopefully this information helps you to visualize reciprocal space. Thank you.