Kinematics of Mechanisms and Machines
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Lecture – 02
Nomenclature and Classification

In this lecture, we are going to look at certain Nomenclatures and Classification of mechanisms of kinematic chains and we are going to define, what are kinematic chains and these will be very relevant for our future course of discussions.

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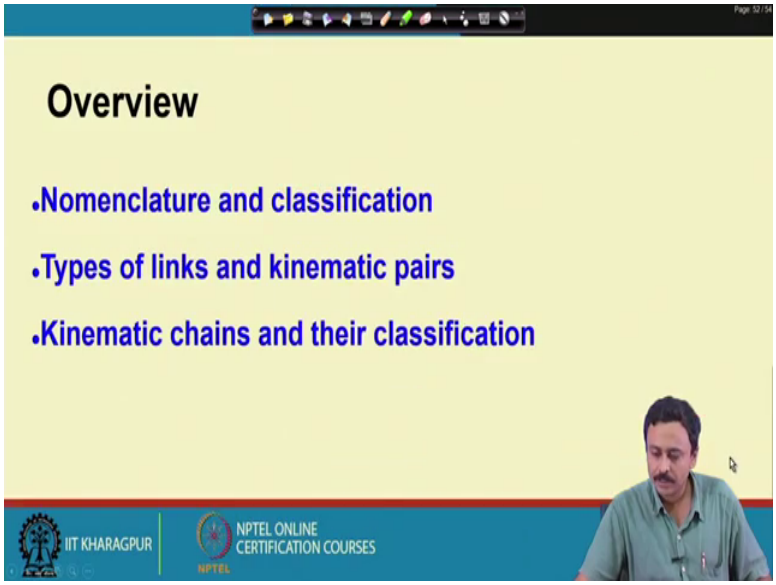

So, here is the overview of what we are going to study. I will talk about links, different kinds of links which as I have mentioned before are rigid bodies which make up a mechanism. I will talk about kinematic pairs which connect these rigid bodies or links, I will talk about kinematic chains that are built using these links and kinematic pairs and classify these mechanisms.

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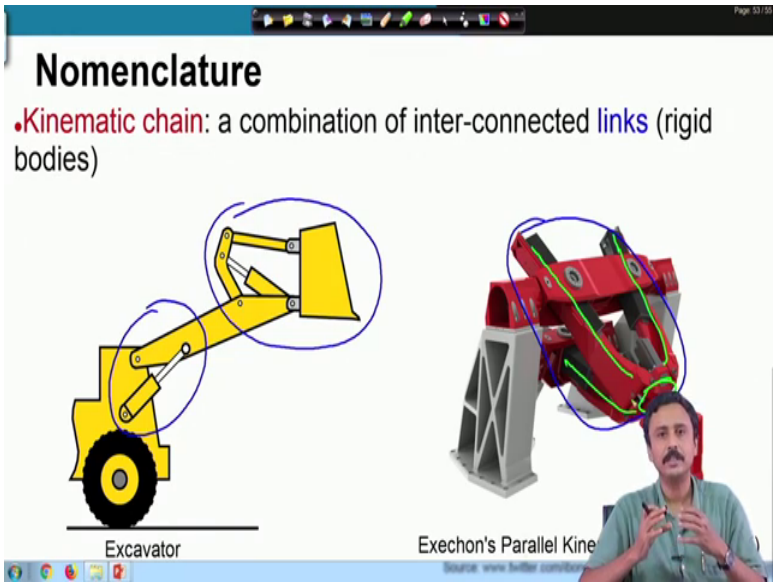

So, what is the kinematic chain? Kinematic chain is a combination of interconnected links which are rigid bodies and these connections actually make a mechanism useful. These connections are not of course, as you can understand they are not welded connections. They, they allow some relative motion between these rigid bodies.

Here is an example of an excavator and an exechon's parallel kinematic machine. So, these are links, here the bin is also a link, this is a link. So, all these parts rigid bodies they are links. Even this actuator, here is an actuator, this is also composed of links. Here is one link and here is the other link and these two links can slide into one another and because this is powered so, it is called an actuator.

So, this is a connection between two links which can slide against one another. So, this is a kinematic chain. This is a kinematic chain. Here is another kinematic chain, here is a kinematic chain where you have these links, this is a link, here is another link, here there is another link, here comes another link, they are all connected through these connection points and they make up a kinematic chain.

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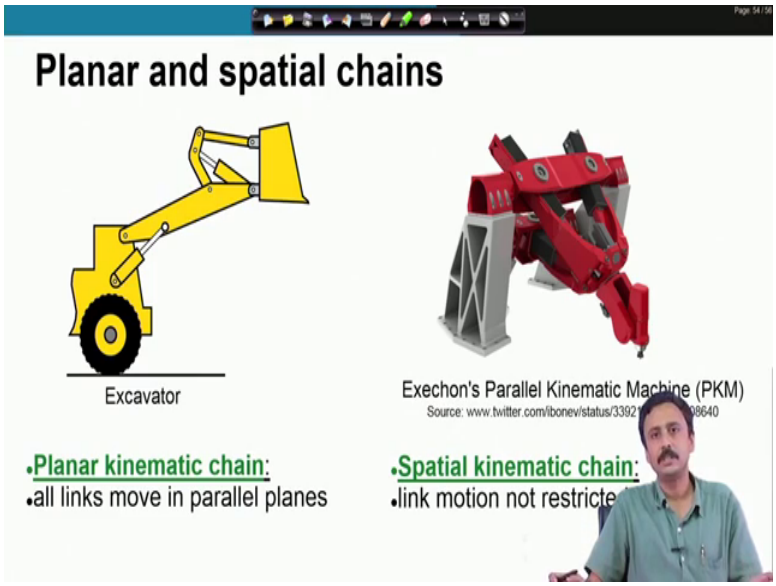

We broadly classify kinematic chains as planar kinematic chain or a spatial kinetic chain. The definition I think is obvious, the planar kinematic chain is one in which all links move in parallel planes as in this excavator. Nothing will come out of this plane of the screen; on the other hand, look at this mechanism, this kinematic chain this machine.

You can have arbitrary motion, it will come out of this plane, it is not restricted to any plane and that is what is required in order to generate complicated motion profiles for the for the tool. So, in a spatial kinematic chain, the link motions are not restricted to any plane.

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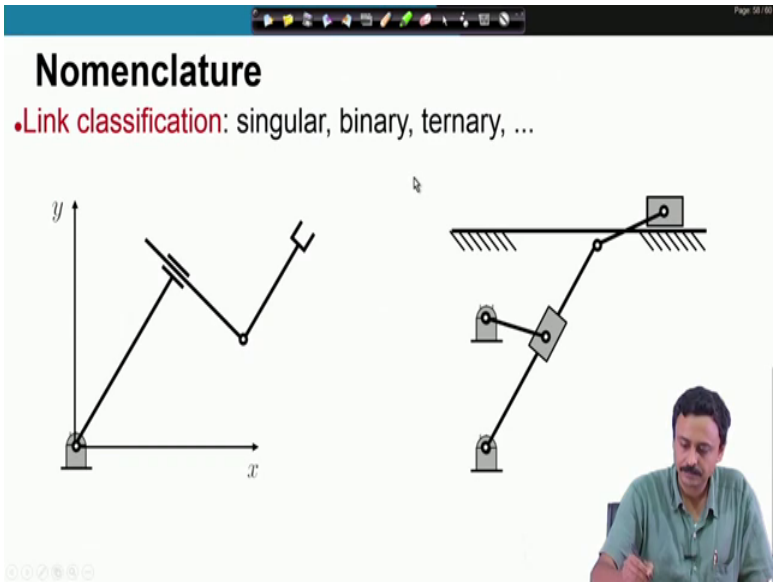

Now, we classify links we classify them as singular, binary, ternary, quaternary, etcetera. Let me show you, a singular link is one in which there is only one connection point, you see this is a connection point and therefore, this link is a singular link. This is a singular link, it has got only one connection point.

A binary link is one in which there are two connection points. So, it connects two rigid bodies; you can very easily identify that this is a binary link, this is also a binary link. For example, this binary link it has got two connection points. This is one connection point, this is another connection point that makes this a binary link. Even the ground is a link, it is a rigid body. How many connection points do we have in this mechanism with the ground. There is only one, there is only one connection point to the ground, ground is also a link in a kinematic chain.

So, ground here is a singular link in other words, I can imagine that this mechanism something like this in which this link is fixed, this link has been fixed. So, ground is also a link. Let us now go over to the mechanism on the right, the kinematic chain on the right. This is a binary link. It has got two connection points; this slider this is also a binary link as I have mentioned that this slider slides against the ground. So, that is one connection point.

So, this sliding connection is one connection point and this hinge is another connection point therefore, this slider is also a binary link. What about this link? This has one, here

there is a sliding connection two and here there is another connection, another hinge there are three connection points for this rigid body; therefore, this is a ternary link, this link is a ternary link. There is another ternary link in this chain, you might have already guessed it is the ground; you see the ground is connected here to the mechanism, here to the mechanism and here to the mechanism. So, therefore, ground itself is a link and is a ternary link.

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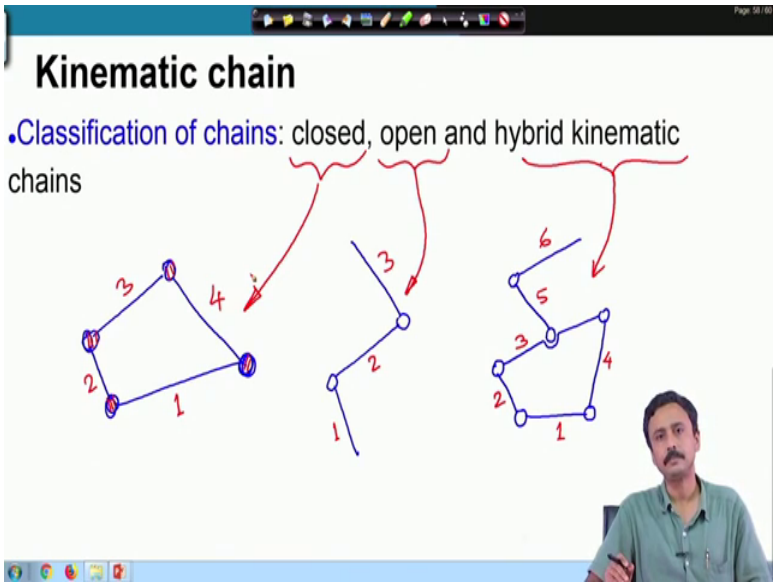

Now, how do you classify kinematic chains? We classify them as closed open and hybrid. What are closed chains? If I draw a kinetic chain, now you have an idea of what a kinematic chain is it is interconnected rigid bodies. So, here I have 4 rigid bodies or 4 links connected by these connections possibly hinges, this is a closed kinematic chain.

So, what is the distinguishing feature of a closed kinematic chain. There is no singular link, there is no singular link in a closed kinematic chain and therefore, it becomes very clear what an open kinetic chain is; for example, this is an open kinematic chain if you number these links. So, there are three links and there are two connection points. This is an open kinetic chain and there are two singular links as you can see. What is the hybrid chain? Hybrid chain is a combination of closed and open kinematic chains.

Let me draw one, this is a hybrid kinematic chain. Let me number. So, we have a closed chain as well as an open chain. There is a singular link, there is a singular link in this chain as well as there are closed chains. There is one closed chain and there are six links

arranged connected in a certain manner this is a hybrid chain. So, this is a hybrid chain, this is an open chain and this is a closed chain.

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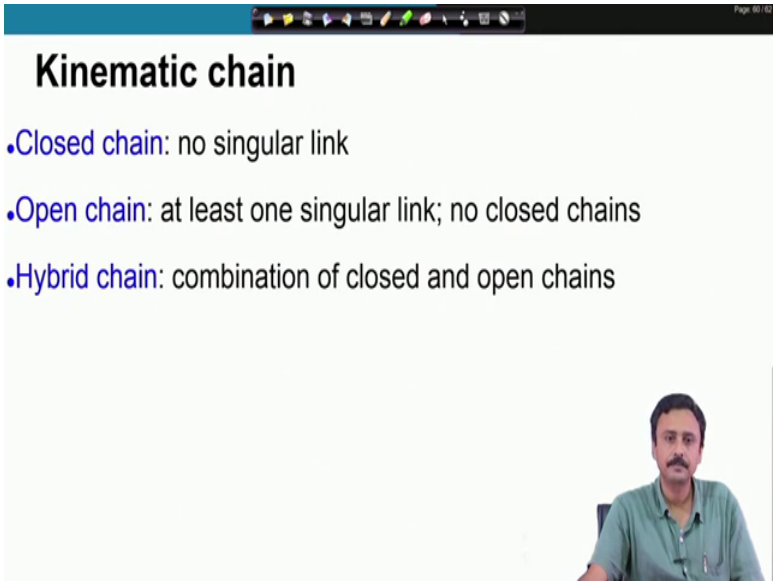

So, what is the Closed chain? A Closed chain is one in which there is no singular link and open chain there is at least one singular link, but no closed chains and what is the hybrid change? It is combination of closed and open kinematic chains.

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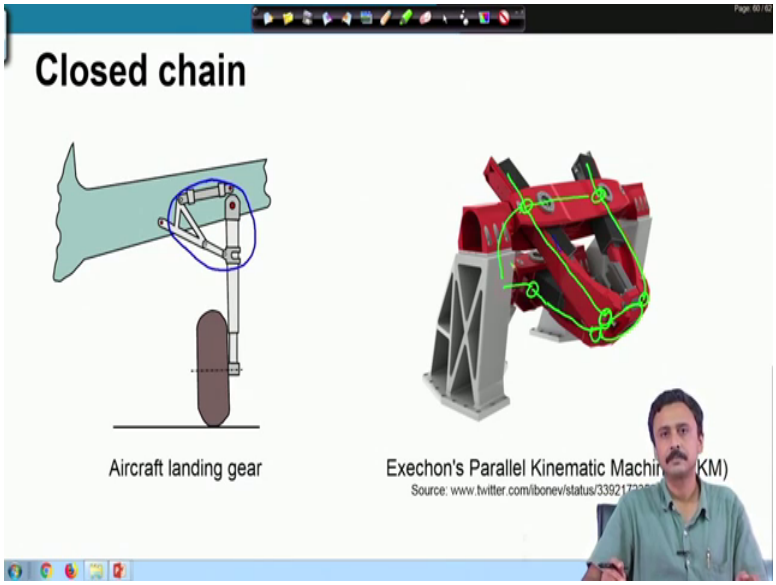

Let us look at some examples. So, this is a closed chain, you can see this forms a closed chain. This is another example of a closed chain, this is a kinematic. So, here is a link,

here is a connection point, connection point; here is a connection point, here is a link below, there is connection point, there is a connection point, there are links they are all connected. So, this is a closed chain.

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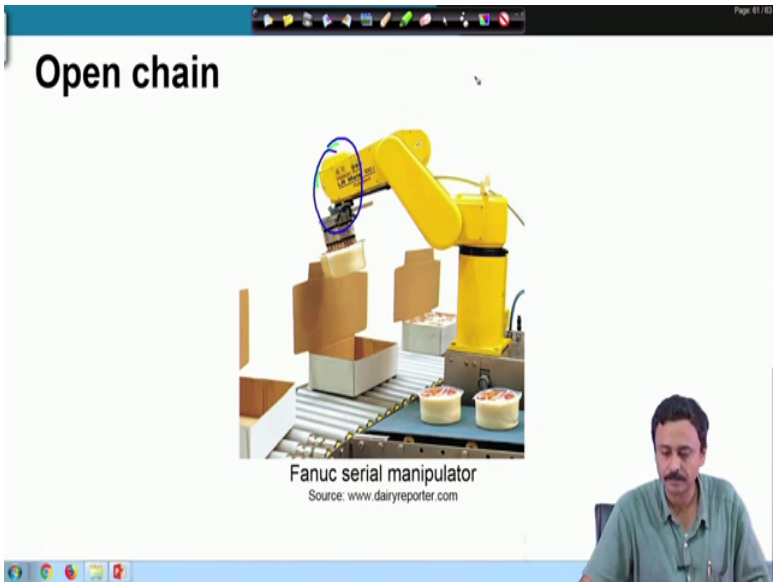

This is an open chain. A serial manipulator is an open chain. You can see as singular link here, a link whether that has only one connection and of course, ground is also singular link.

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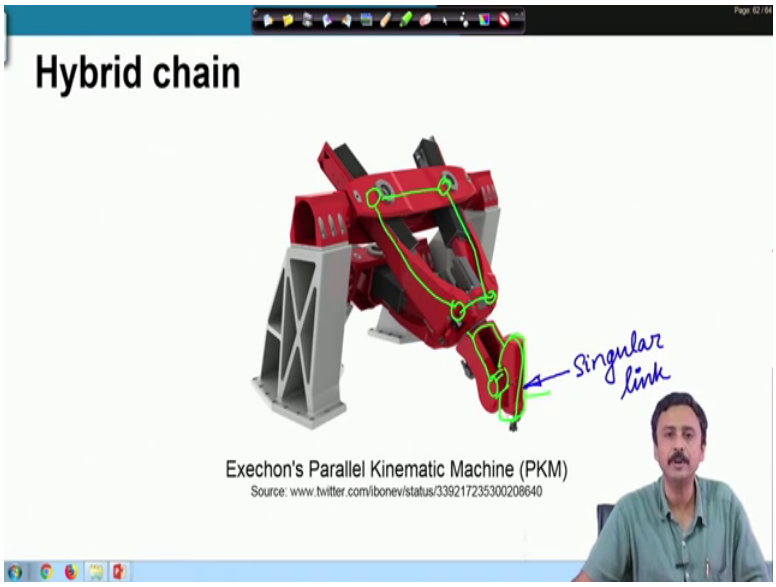

Hybrid chain, now this has closed chains and it has open chain as well. Here, this is a singular link. You have a singular link. So, this is the hybrid chain.

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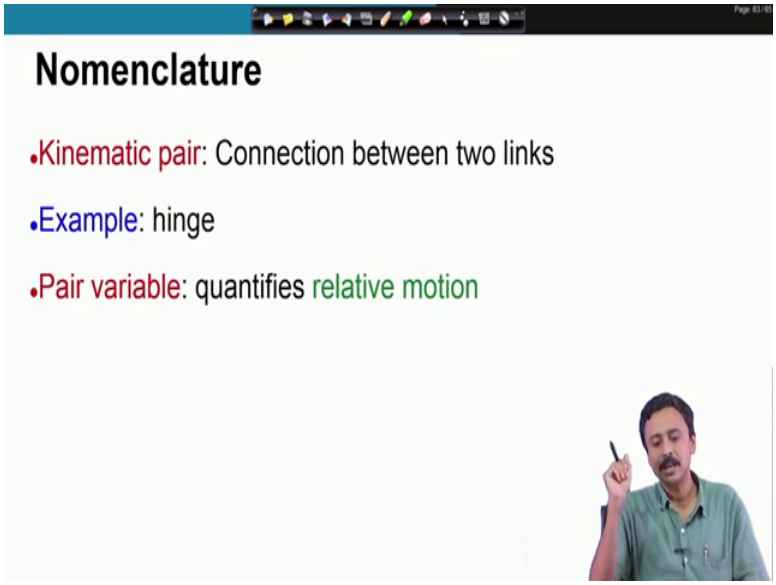

Now, what are Kinematic pairs? Essentially in very simple terms, these are the connections between two links, two rigid bodies; an example is a hinge a hinge allows rotation. So, it is not a connection which will not allow in relative motion. It is a connection that will allow relative motions for example, a hinge allows relative rotation of two links.

Now, as soon as you have relative motion, you need a variable which tracks keeps track keep keeps track of the this relative motion. For example, you can say in a hinge the angle between the two links, the angle between the two links will keep track of the relative configuration of the of the kinematic pair; such a variable is known as a pair variable.

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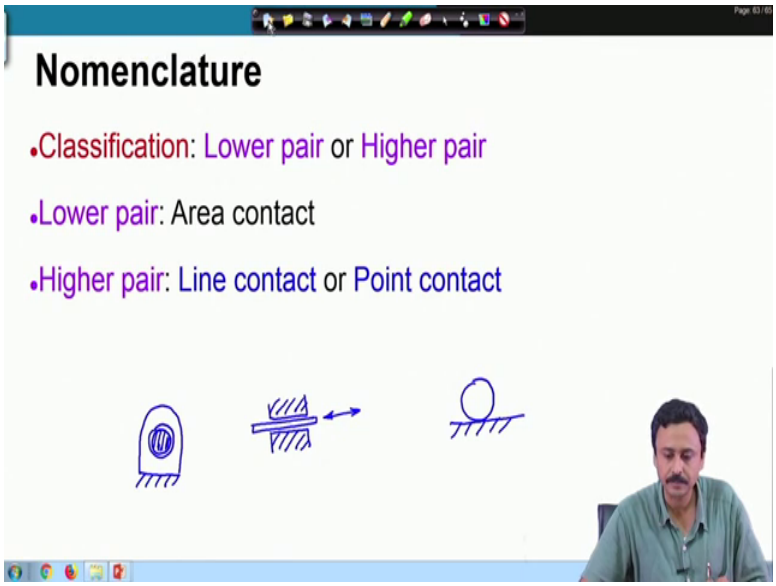

So, the pair variable quantifies the relative motion between two links. Again this kinematic pairs also have classification as lower pair or higher pair. A lower pair is one in which you have area contact and a higher pair is one in which you have line or point contact. Let me quickly give you an example; the hinge, this has area contact or at least we expect that to have an area contact. It should not allow free play or a guide through which the link slides that also has area contact these are lower kinematic pairs.

On the other hand, higher pair contacts are like between a cylinder and ground. It is a line contact or a sphere and the ground the point contact. So, these are higher kinetic pairs.

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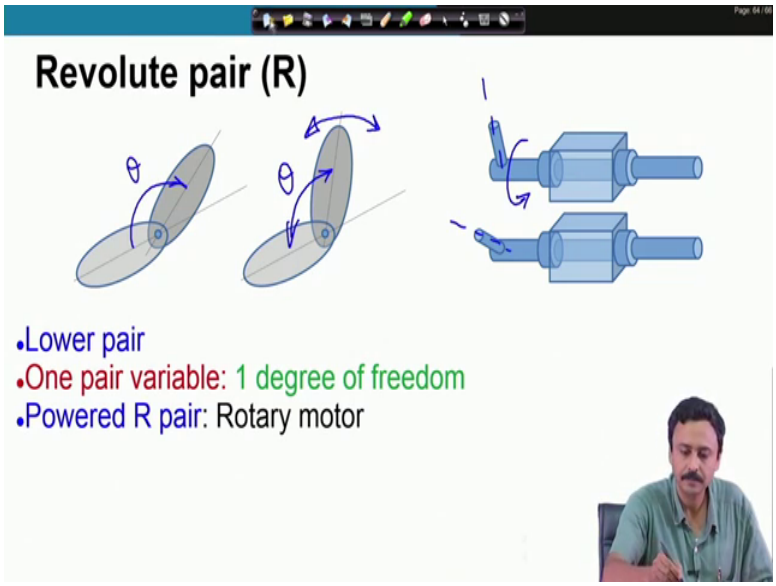

Now, I am going to show you various kinds of typical kinematic pairs that are found in mechanisms revolute pair. This is the simplest kinematic pair is a hinge to be what we call as hinge. This is a three dimensional visualization of a hinge.

So, a hinge allows this rotation and you have this is relative motion between these two, these two rigid bodies tracked by this angle. Here; for example, it is this rotation. So, tracked by the angle, a hinge or a revolute pair as we call it formerly a revolute pair is a lower kinematic pair, it has one pair variable. So, we say it has got one degree of freedom.

So, degree of freedom is the minimum number of variables that need to be specified to fix the configuration of the kinematic pair. So, if I say this angle should be let say 90 degree, then it fixes up this kinematic pair here you specify the angle and it fixes up the configuration. So, we have one pair variable and we have therefore, one degree of freedom. A powered R pair revolute pair is a rotary motor.

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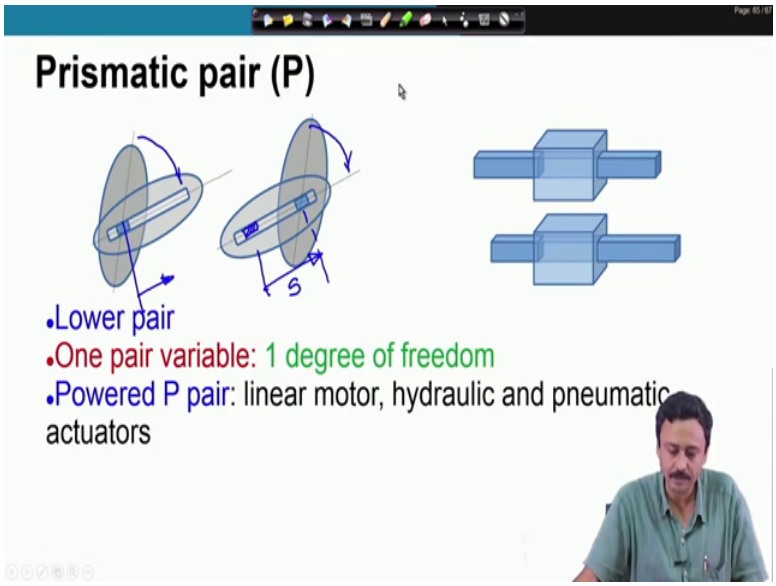

Next, we come to prismatic pair; three dimensional visualization is shown on the right. Here, as you can see this angle remains fixed. So, this angle remains fixed but what changes is just sliding. So, initially the slider was here it moves, it slides in this guide, but the angle remains fixed therefore, by specifying how much distance the slider has slid. I can specify the relative configuration of these two links.

Once again as I have mentioned a prismatic pair P pair is a lower kinetic pair because it has area contact. It has again one pair variable. So, it has got one degree of freedom here the pair variable is S what I have shown you in this figure. A powered P pair is a linear motor it could be a hydraulic or a pneumatic actuator as well. So, in a hydraulic or pneumatic actuator you have relative sliding between two links, two rigid bodies and that is powered that is a powered P pair.

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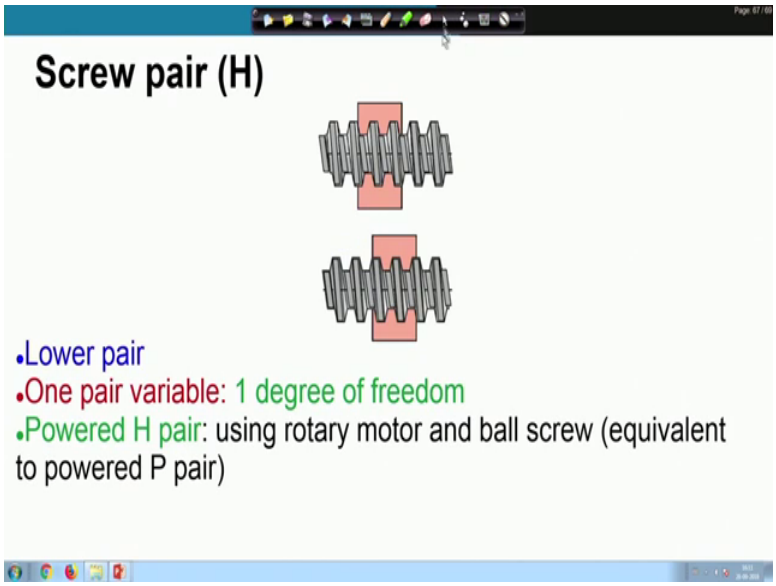

Next, we come to this Screw pair. As you all know when a screw rotates the nut can translate if you hold if you do not allow the nut to rotate, then the nut will translate as the screw rotates the nut will translate. So, it is this translation, this translation which becomes our pair variable but this pair variable can be related to the lead of the screw as you know it can be related to the lead of the amount of rotation through the amount of rotation and the lead you can determine the translation of the nut.

So, this can also be called the sliding pair variable and as you realize that the contact between the screw and the nut is area contact. So, this is a lower kinematic pair. It has one pair variable; either you can consider rotation as the pair variable or the shift or translation of the nut as a pair variable. So, it has got 1 degree of freedom.

A powered H pair you if you use a rotary motor with a with a ball screw that forms a powered H pair. So, it is equivalent to a powered H pair is equivalent to a powered P pair.

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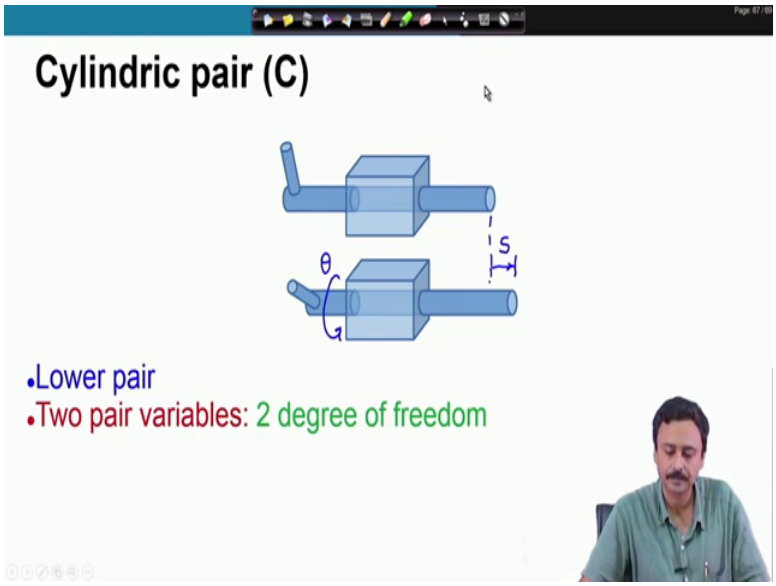

Next, we come to cylindric pair. What is the Cylindric pair? Here, I can have translation of this cylinder which is sliding through this guide as well as I can have rotation of the cylinder.

Therefore, I need two variables to completely specify the configuration relative orientation of these two links the guide and the cylinder. I require two variables; one is S, the other is theta and here you again realize that this is area contact. Therefore, this is a lower kinematic pair. It has got two pair variables theta and S as I have discussed. So, it has got 2 degrees of freedom; you must specify these two quantities in order to completely fix the cylinder in it is guide.

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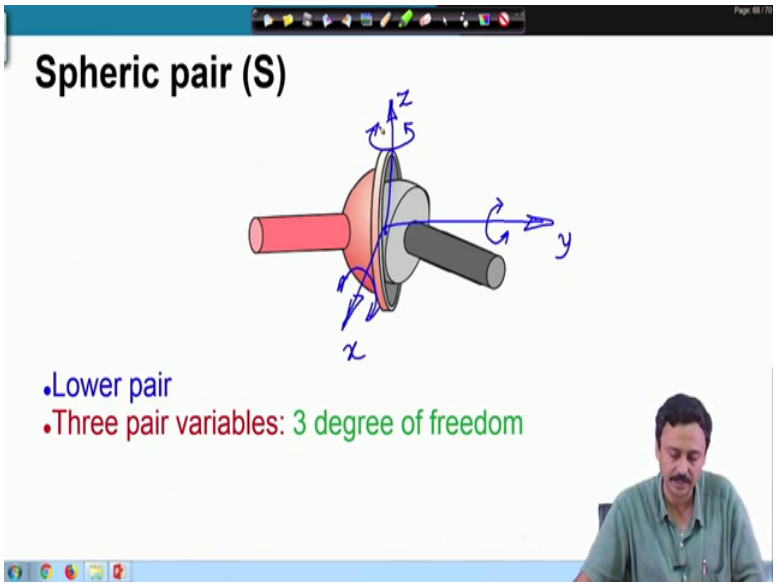

A spheric pair typically, we call this as ball and socket joint again this is an area contact. So, it is a lower pair, it has got three pair variables. So, it has got three degrees of freedom just to understand what are these three pair variables. You consider this orthogonal coordinate system, then this spheric pair a rest pair allows rotation about x, y and z axis.

Therefore, you need to specify these three rotations in order to fix the relative configuration of these two rigid bodies two links, it has got 3 degrees of freedom.

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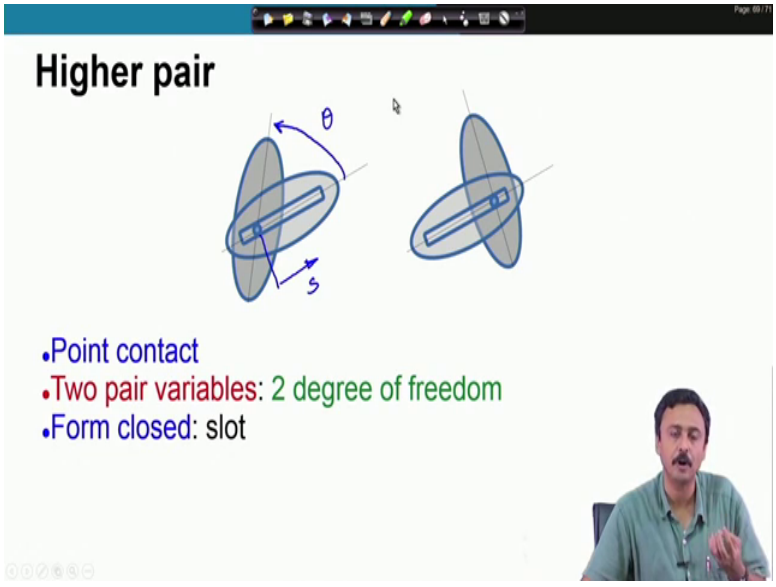

Now, we come to higher pairs. Here, I have shown two links with a pin which moves in a slot this pin allows not only translation but it also allows rotation and there is point contact between the pin and the guide there is point contact between the pin and the guide.

Therefore this is a higher kinetic pair. It has got two pair variables as just now, I mentioned the sliding distance and the angle and this kinematic pair is maintained or the contact is maintained by the form of the guide. So, this is known as a form closed kinematic pair.

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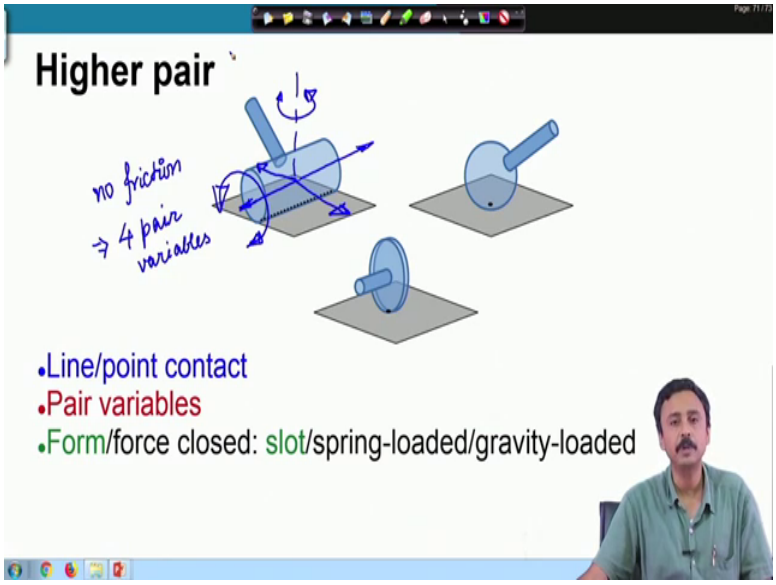

So, the slot forms the form closed kinematic pair. Here are other examples of higher pairs depending on the kind of shape, you can have line contact, you can have point contact of this form. Pair variables can depend on whether you have friction or whether you do not have friction.

For example, if you do not consider friction, if you do not consider friction, then this cylinder can translate in this direction. It can translate in this direction, it can rotate about this axis. It can rotate about this axis; of course, we are considering that the contact is maintained under this assumption. So, it can translate in these two directions, it cannot translate in the vertical direction if the contact will be broken and it can rotate about one horizontal axis and the vertical axis.

So, if you do not consider friction, this has 4 degrees of freedom. So, 4 pair variables but if you have friction, then let us see no friction there are 4 pair of variables two for translation and two for rotation. Now, if you have friction, then what happens?

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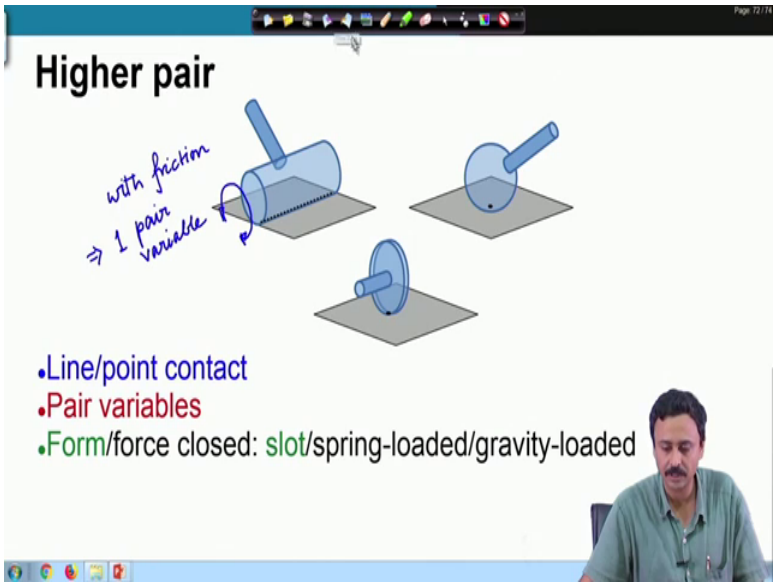

If you have friction and no sliding, you have friction which will not allow sliding, then you see it can only roll. You can only roll it, cannot slide sideways, it cannot translate forward or backward. We can only roll it, cannot rotate about the vertical axis as well so.

With friction, there is only one pair variable. So, pair variables can depend on whether you have whether you allow pure rolling or you allow sliding as well; whether you have friction or you do not have friction; that means, you allow sliding even with friction you can have sliding of course, but if you do not allow sliding, you say that it is rolling then it has got 1 pair variables. It is got 1 degree of freedom but if you allow sliding, then it has got 4 pair variables, you can do similar analysis for the other kinetic pairs.

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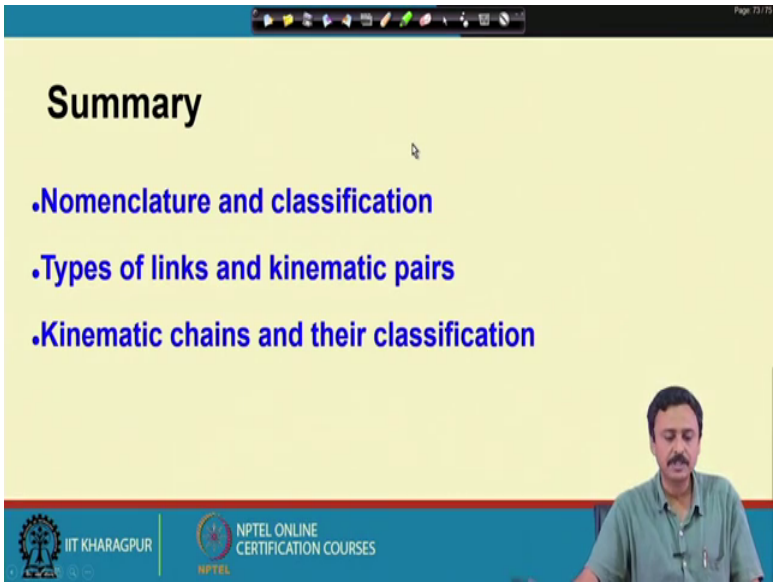

So, let me summarize we have discussed in this lecture the various nomenclatures that we will keep using from time to time in our discussion on kinematics. We have classified kinematic chains, we have classified kinematic pairs. You looked at different kinds of links, different kinds of kinematic chains and very importantly, we have discussed what is known as pure variable. This is a very important concept as we will see in the discussion of degree of freedom this pure variable plays a central role. So, with that I will close this lecture.