Kinematics of Mechanisms and Machines
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Lecture – 01
Introduction and Motivation

Welcome to this course on Kinematics of Mechanisms and Machines. Today, in this first lecture, I am going to introduce you the subject matter of study. And I will set the aim and scope of this study. Later on I will show you some examples for motivation and also discuss about the issues that are relevant for our studies in the mechanisms shown.

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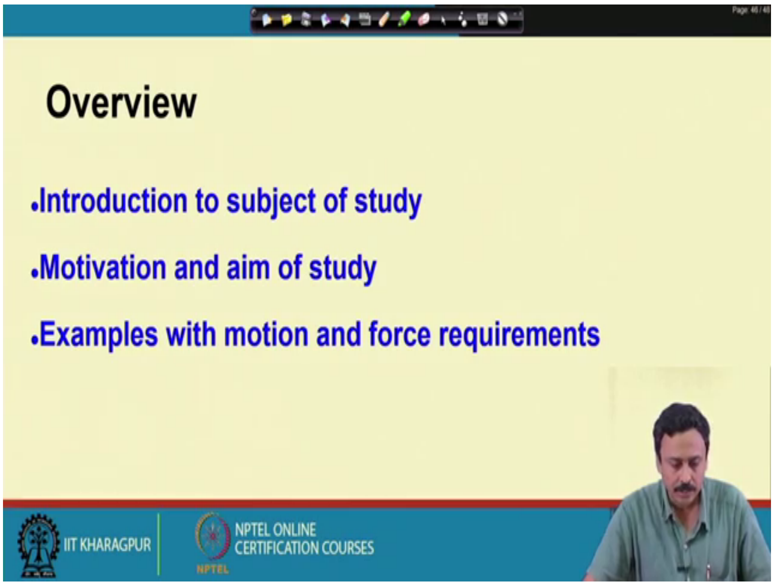

So, this is the overview of today's lecture. As I have mentioned, I will motivate you why we should study this subject, and discuss the aim what we wish to achieve in this course. Then I will show you these examples where I will discuss the motion and the force requirements.

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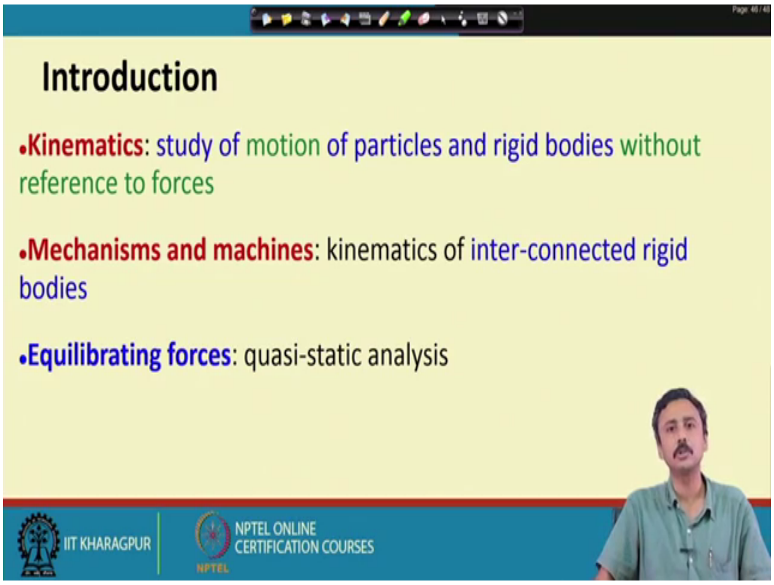

As you know kinematics is the study of motion, essentially study of motion of particles and rigid bodies without reference to forces. So, these are the forces that produced the motion. So, we are not interested in the relation of motion to the applied forces, but only the motion. How motion is related from an input to an output of a mechanism or a machine.

Now, when we come to the kinematics of mechanisms and machines, it is the study of kinematics of interconnected rigid bodies. You have rigid bodies connected in various ways which form a mechanism. How let us say the input which might be an actuator gets transferred and transformed to an output. What is the motion relation, what is the velocity relation, what is the acceleration relation; typically this is the straight thing that is studied.

Apart from this, in this course, we are also going to look at equilibrating forces that come in these mechanisms and machines. What are these equilibrating forces? For example, I have a mechanism. Here it is my hand and it is applying some force, what are the forces developed by muscles if I ask this question? Now, this is not under the purview of forces that generate motion, but forces that equilibrate or if I want to apply a particular force, what should be the forces applied by my muscles. So, it is a transformation of forces, this also can be studied under kinematics.

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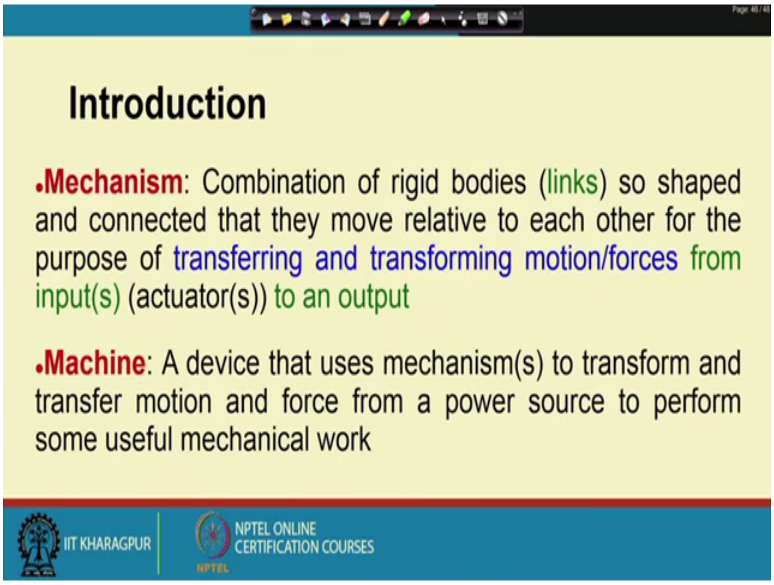

Let us come to this formal definition of a mechanism. What is a mechanism? Mechanism is a combination of rigid bodies which we call links so shaped and connected that they move relative to one another for the purpose of transferring and transforming motion or forces from inputs to an output. So, as I have mentioned that not only motion can be transformed and transferred from an input to an output, but also forces. So, this is the formal definition of a mechanism.

Now, what is a machine? A machine is a device that uses mechanisms there can be one mechanism or there can be multiple mechanisms to transform and transfer motion and forces from a source of power to perform certain useful mechanical work. In this therefore, we have automobiles which do useful work, transferring loads, transferring people. We have machines that are used for manufacturing like milling machine, drilling machine, shaping machine, they are all machines which do useful mechanical work. On the other hand, when we talk of a watch or a clock, we do not call it a machine, though it does useful work, but not useful mechanical work. It is very useful, but we usually it refer to clocks and watches as mechanisms, because in clocks and watches is the motion that is of primary importance rather than mechanical work that is done.

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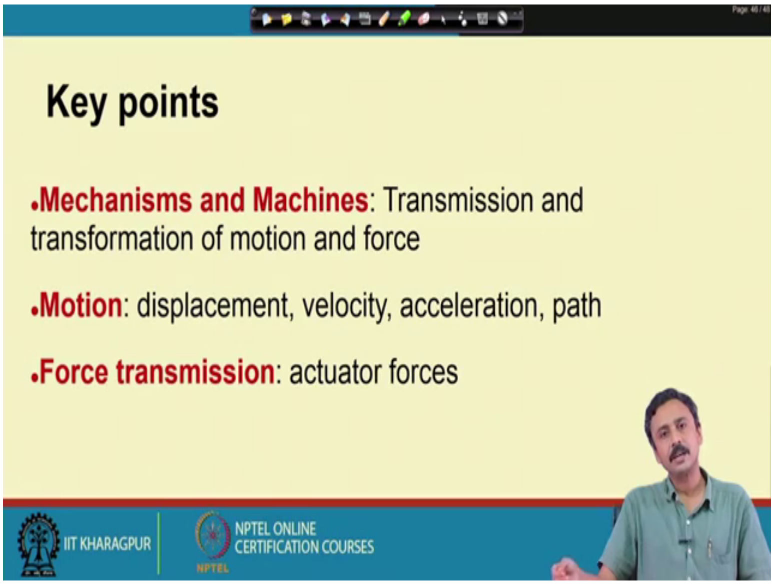

So, I have listed here the key points. We have mechanisms and machines which are used for transforming and transmission of motion and forces. Now, motion how do we quantify or understand motion. So, motion is quantified in terms of displacement, in terms of velocity, in terms of acceleration and in terms of path. For example, a robot mechanism will be expected to follow a certain path. The motion can be quantified in terms of these four quantities. And the transformation and transfer of these motions from the actuator to the output is under the purview of study of kinematics of mechanisms and machines.

As I have already mentioned force transmission; the force that force or torque may be that an actuator or a motor exerts is getting transferred to move certain load or do some mechanical work or generate motion like in a clock. So, this force transmission is another important aspect of this study.

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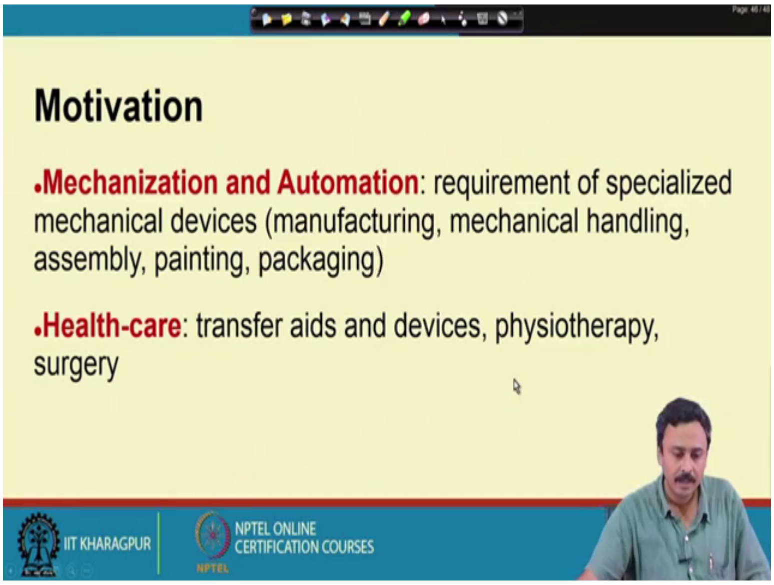

Now, why we should study I mean this is the first question that arises, why we should study kinematics. As you know that we have lot of mechanization automation which requires specialized mechanical devices. For example, in manufacturing, in mechanical handling, in assembly, in painting, packaging; in order to handle parts, in order to transfer parts, or in order to do machining in a certain way in a certain path, we all understand the utility or importance of mechanization and automation. We have robotic mechanisms, robotic devices, which perform automated assembly operations, welding operations, material handling operations, packaging, painting, etcetera.

So, to understand how these devices work, we need to understand that kinematics. This is another very important issue that has come up in recent years and that is in health-care. You require to transfer patients maybe who have undergone surgery to move let us say from a lying down position to a sitting position, or from sitting position to standing position, or people with disabilities in order to have physiotherapy for such persons. And in surgery it is a very important application of mechanical devices.

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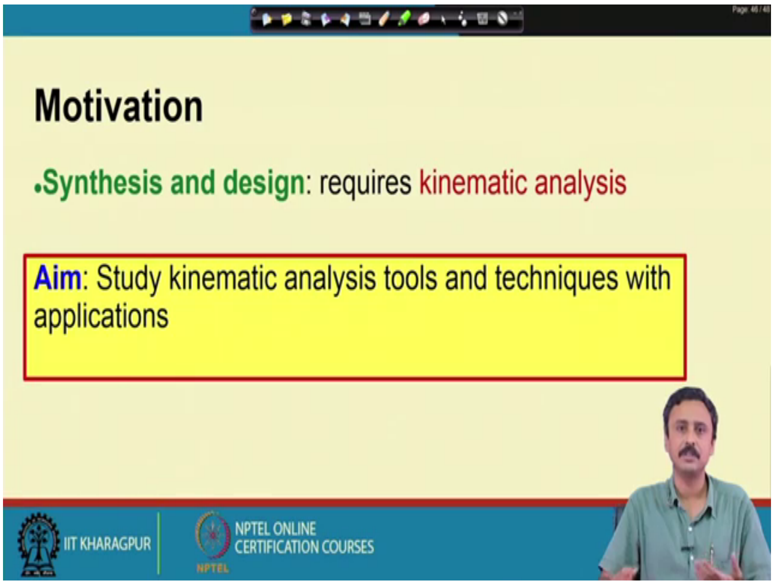

So, what is the purpose of studying kinematics? When you design such mechanisms such machines, then you need to understand how the motion will be transferred from a certain actuator to certain output. Let us say a surgical device, how will it transfer the motion of the surgeons fingers to perform a particular surgery. So, in order to synthesize and design these mechanisms, you need to study kinematic analysis with what velocity will a device will transfer a patient from sitting to a standing position with what acceleration what will be the force requirements. So, these motivate are these the issues motive us motivate us to study kinematics kinematic analysis of mechanisms and machines.

So, we set our aim as follows, we will study kinematic analysis tools and techniques with certain applications. So, at the end of this course, you should be able to analyze a given mechanism for input-output motion relations, velocity relation, acceleration relation, or in a robot how a path is can be planned. Or in a gear transmission, for example, how a gear transmission works. And what, what in what way it, it transforms and transverse motion.

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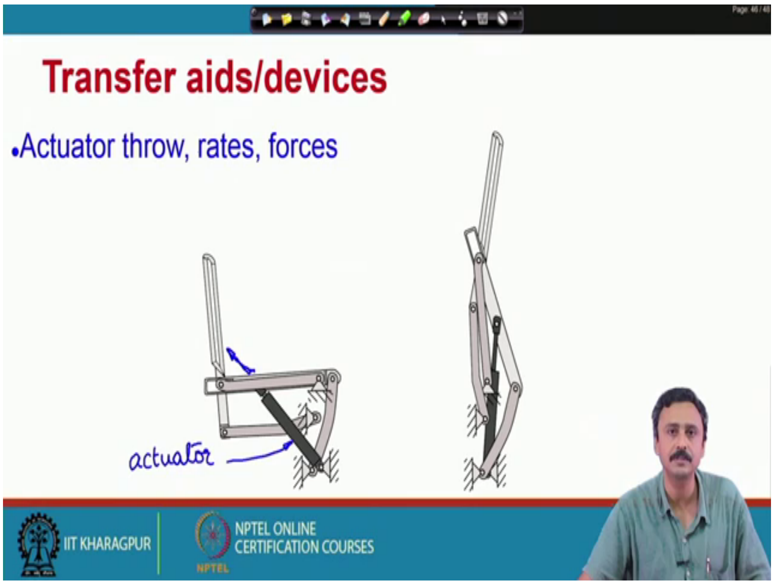

Let me now give you some examples. As I have been mentioning transfer aids and devices for patients who have undergone surgery for example. This is a chair in which you have an actuator. Here is an actuator which can expand in this direction, and as it expands of course, it will rotate. And let us see what it does, it takes this chair from the sitting position to the standing position.

Now, what are the issues kind of issues relevant to our study kinematic analysis of mechanism, this is a mechanism. What should be the throw of the actuator? How much should this actuator which can be a pneumatic or a hydraulic actuator, how much should it expand in order to take this chair from the sitting position to the standing position? This is a relevant question that one can ask.

So, what should be the size of the actuator? What should be the rate at which it expands? So, that a person is taken gradually from the sitting position to the standing position without much acceleration without causing discomfort to the patient. What kind of forces the actuator needs to apply in order to lift a person of a certain weight from the sitting to the standing position. So, these are the issues that we can discuss under when we analyze such mechanisms.

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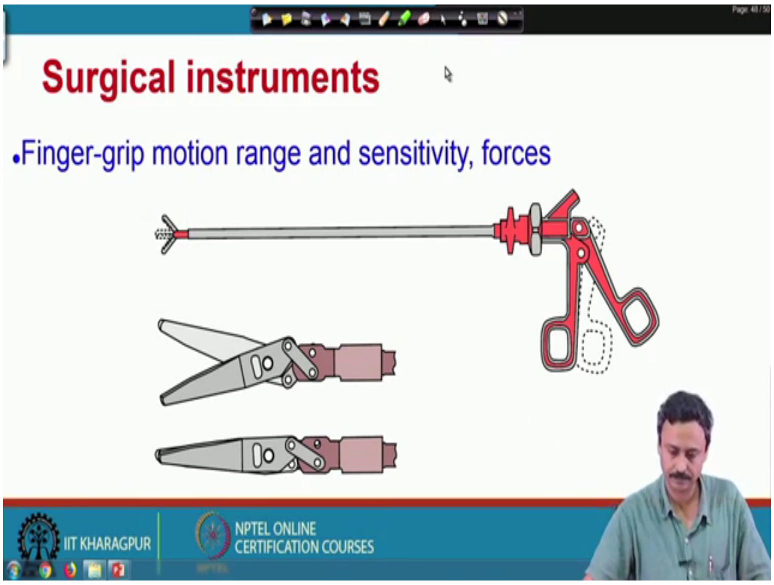

Next as I mentioned about surgical tools here is a surgical. And here is a surgical instrument which is typically used in laparoscopic surgery. So, as you know in a laparoscopic surgery, the surgeon makes incisions on the patient's body, and sends in the laparoscope and such surgical devices to perform an operation. Now, what is expected of such a surgical instrument? It will transfer the motion of the surgeon's fingers in order to perform certain surgery. What kind of end effectors can be there at the end of this instrument? There can be a pair of scissors like this which performs the actual surgeries or there can be clamps.

Now, when you perform a surgery, when a surgeon performs a surgery, he can position his fingers for example, to an accuracy of a millimeter. And when he is performing small surgeries, micro surgeries, he is expected to control the accuracy of the scissors to maybe some millimeter level. Therefore, this mechanism is expected to transform motion in such a way that the accuracy of the surgeon's fingers is enhanced by the instrument, or maybe when he is clamping the force the surgeon should be able to experience the force that he is putting, he should not put too large forces. So, what are the issues? As I mentioned this finger grip, motion, range, sensitivity, the force that the surgeon has to apply in order to move the scissors. So, these are issues which are relevant to our discussion on kinematics.

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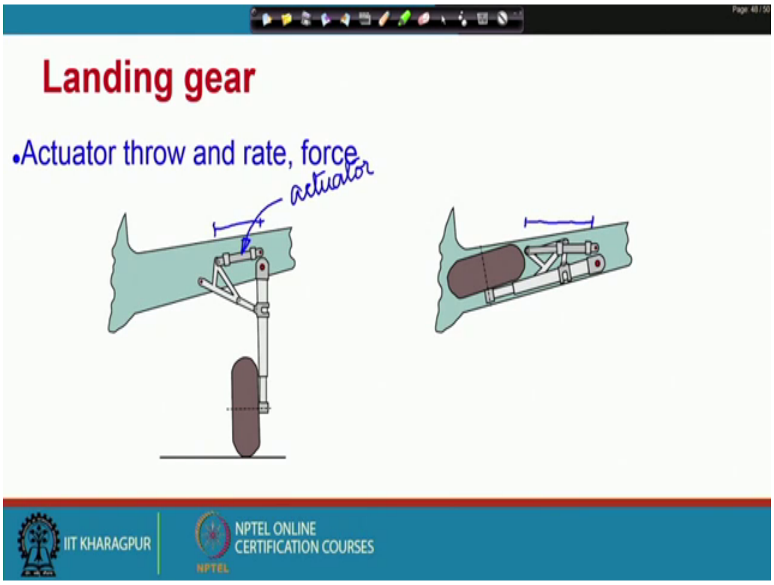

You have seen an aircraft; when the aircraft is on the ground the wheels are open and it rests on the wheels, but when it takes flight the wheels are folded. The mechanism that allows this aircraft to do that is known as the landing gear, the aircraft landing gear. Here is a schematic of an aircraft landing gear. As you can see from this open position to this folded position. Here again you have an actuator which has expanded. You can see this, here it has expanded initially it was of this much length.

Now, it has expanded to fold the wheel in h ere what is of importance again the actuator throw how much should the actuator him expand in order to fold the wheel in what at what rate. What will the forces required to bring up the wheel into the folded configuration. So, this will allow you to for example, choose or do the actuator sizing what kind of actuator’s, and what should be the peak force required by the actuator by the actuator, all those calculations are possible.

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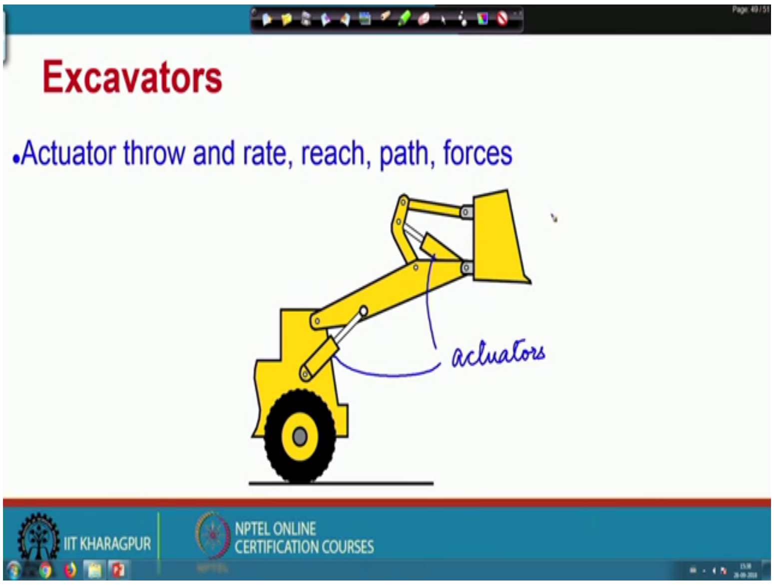

You have seen excavators in construction sites. Here I have shown you an excavator. Here are these actuators which are usually hydraulic. How much should these actuators expand in order to let us say bring this bin to this configuration? What should be the throw of the actuator to bring the bin to this configuration? At what rate should the actuators expand: so that this bin moves maybe in this horizontal direction parallel to the ground.

And what kind of path is to be generated. For example, it has to generate a straight line path suppose it has to generate a straight line path. How should the actuators expand? There are two actuators as I have shown you how should they expand what should be the coordination between these two actuators, so that the bin moves in a straight line. What kinds of forces are expected of the actuator to lift a certain load? So, these are the issues that can be discussed under kinematics.

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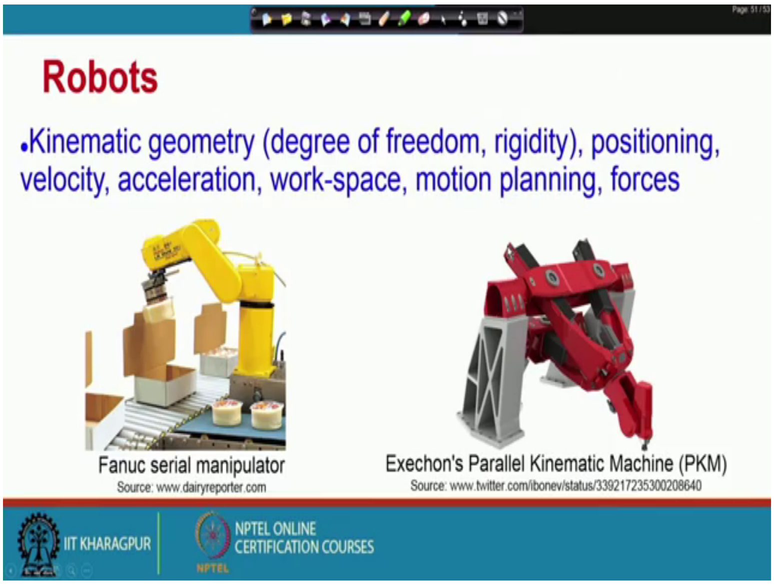

We all know how useful robots are in mechanization in automation. Here, I have shown you an example of a robot which is being used for packaging. Now, this is a repetitive task and has to be done with care with precision in many situations, where you have to pack delicate items. So, how should these actuators work? Now, here on the on this in this figure, I have shown you what is known as a serial manipulator a serial robot from Fanuc. You also have something called parallel actuators. Here is the Exechon's parallel kinematic machine as it is called. This is used for machining purposes. You can imagine that this kind of a structure is very robust. Therefore, it can be used for precision manufacturing precision machining.

Now, what are the issues related to robots what kind of kinematic geometry what kind of structure you should have for doing a certain kind of task. For example, in this serial manipulator which is just packaging some dairy products, possibly the requirements of motion will be limited it will pick up something from the conveyor and packet put it in a box. But the parallel kinematic machine that might have to generate very complicated motion profiles to machine a certain let us say channel on a work piece. So, you need require a lot many degrees of freedom for this kinematic parallel kinematic machine in order to be useful.

Positioning, how should the actuators expand, what should be the velocity or the coordination between actuators, so that a certain path is generated, what will the workspace of this of these machines, how much will be the reach of the robot on the work piece. How large work piece it can handle? How do we plan motion? How do you coordinate actuation the different actuators and motors, so that a certain path is generated. What will be the forces that the actuators must supply in order to let us a lift a package from the conveyor or how much force an actuator should apply in order to machine over piece. So, these things are discussed under kinematics.

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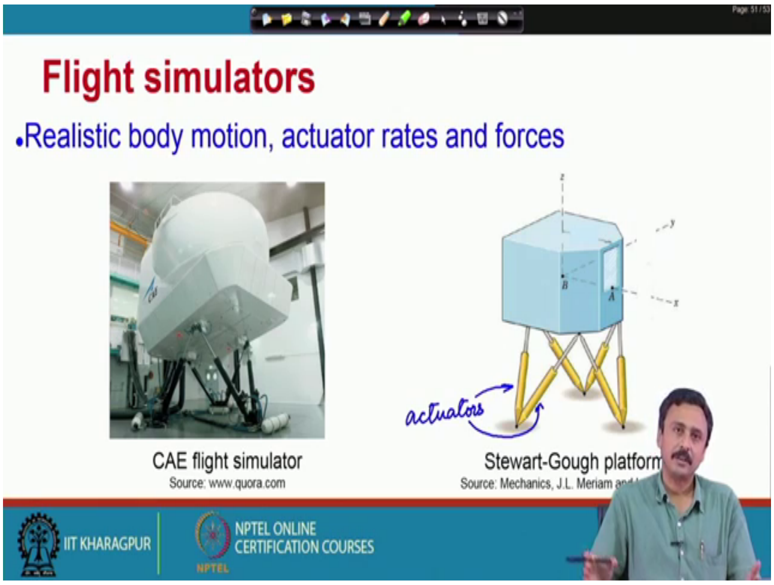

As you know that pilots they require continuous training; training for takeoff landing, for facing turbulent atmospheres air pockets. How do you train a pilot in such situations? So, we have flight simulators. So, in a flight simulator essentially the mechanism is like this. What I show on the right is called a Stewart-Gough platform. It has got multiple actuators as you can see. Now, what when these actuators do? They will position the platform, and they will try to simulate certain motion conditions.

For example, when it is taking off, the motion capsule must incline in certain way it must move it must translate and rotate all these are being produced by these actuators. Let us look at the issues related to two flight simulators. In order to produce realistic body motion, you have to program these actuators to produce a certain kind of motion for the capsule. So, how do you how do you calculate these motions that are required, let us say for takeoff for landing for giving a turbulent motion to the capsule. What will be the actuator rates in order to produce a certain motion and the forces in order to generate a certain feeling for the pilot, the forces to move the capsule and to generate a certain kind of velocity or disturbance which will simulate let us say an air pocket or a turbulent atmosphere. These are the issues that are discussed under kinematics again for these kinds of mechanisms.

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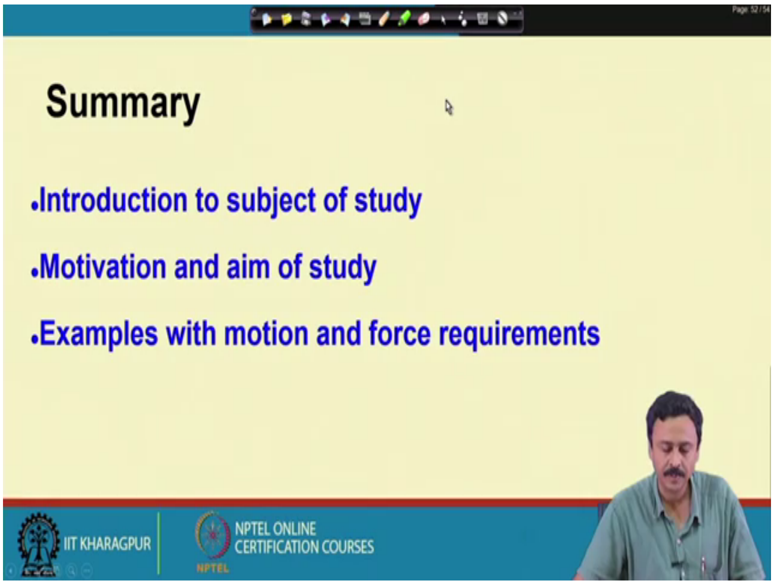

So, let me summarize what we have discussed in this lecture. I have introduced the subject that we are going to study. I have given you the motivation why we should study the subject, and set the aim that we are going to follow in this subject. I have given you examples, and also shown you; what are the issues that are relevant to the study of kinematics in these examples.

So with that, I will close this lecture.