

**Introduction to Internet of Things**  
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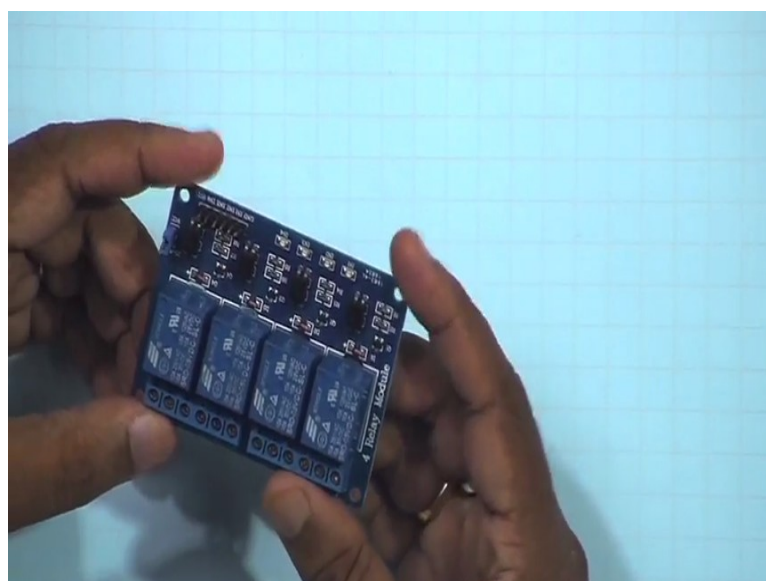
**Lecture – 04**  
**Actuation**

So, this particular lecture is on actuation. So, based on the readings of the sensor, we have already seen different types of sensors in the previous lecture and based on the readings of these different types of sensors, some action might be required to be taken and that is done by actuators. These actuators basically perform certain actions on the environment on another system on a device and so on.

So, there are different examples of actuators. I am going to show you a different type of actuators very shortly, but these actuators, they can have principle of working principles which are based on electronics, then electrical, then you know mechanical systems and so on. So, they basically you know use some kind of control behavior, some control signals are sent. So, this is how these actuators, they perform.

We are going to go through the different mechanisms behind the functioning of these actuators in this particular lecture.

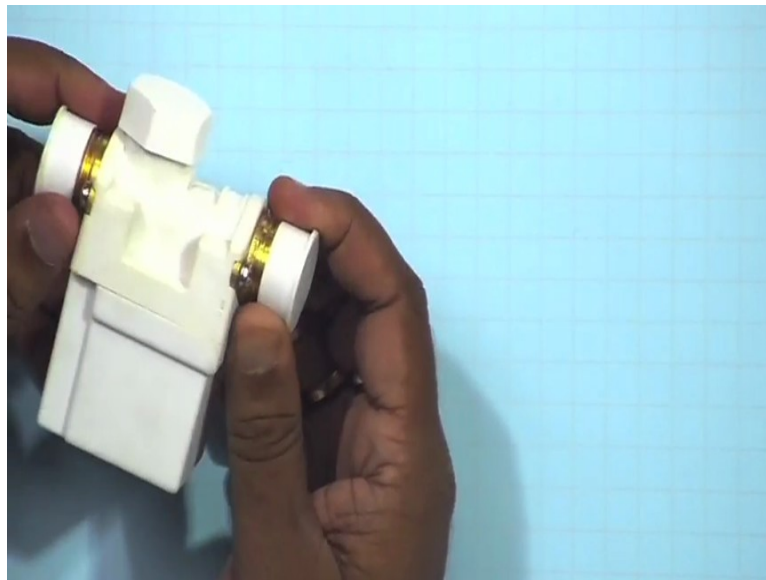
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Before we proceed, I wanted to show you at the outset some of these actuators that can be used. So, here is an example of a sample actuator which is known as the relay switch. So, this relay switch, it is an electromechanical switch which can be used to switch between AC and DC for instance or different other things can be performed. So, the sensor networks, the sensor nodes, they typically operate in DC and based on the sensed value maybe you know you want to switch off the electricity in your room or at your home based or maybe something, maybe fire has been detected by the sensor network, then you want to do something or you want to turn off the power in your home.

So, that is AC that operates on AC, right. So, this particular switch, this electromechanical switch will basically turn off AC that the power supply at your home. This can help in doing it. So, this is an example and this is known as relay.

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There is another one which is the solenoid valve and this basically can help in controlling the flow of liquid. So, you have an input; you have an output. So, we have an input, we have an output and the solenoid valve if we open it, so what we can see over here is what is inside. So, you know water can flow in and depending on the conditions, this valve is going to either allow the water to flow out or it is going to stop. It is not going to allow.

So, this is another actuator. Like this there are different actuators that are available for use in IoT. So, having seen some real life actuators, let us try to understand the basic principles of actuators, but before that let us go through some of the basics.

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### Actuator

- ✓ An actuator is a component of a machine or system that moves or controls the mechanism or the system.
- ✓ An actuator is the mechanism by which a control system acts upon an environment
- ✓ An actuator requires a control signal and a source of energy.

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So, an actuator is a component of a machine or a system that moves or controls the mechanism of the system. So, typically these actuators are based on some control system and these control systems, they act on the environment. So, an actuator basically requires some kind of a control signal and a source of energy for their functioning.

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- ✓ Upon receiving a control signal, the actuator responds by converting the energy into mechanical motion.
- ✓ The control system can be simple (a fixed mechanical or electronic system), software-based (e.g. a printer driver, robot control system), a human, or any other input.

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graph LR; A[Electric Current Voltage] --> C[Control Signal]; B[Pneumatic Pressure, Hydraulic fluid] --> C; D[Manual Drive e.g. crankshaft] --> C; C --> E((Actuator))
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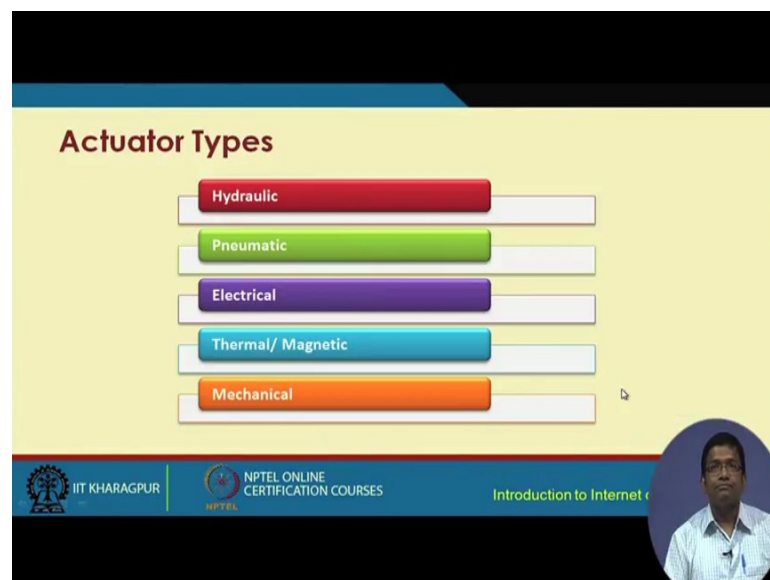
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So, typically I said that control signals are required for the actuators. So, when these actuators receive a control signal, they respond by converting that energy into mechanical motion. Some mechanically something is going to be done. This is an

example of course. So, they convert that electrical signal, some control signal into mechanical motion and that control system can be simple which can be based on some mechanical or electronic system or it can be software based like a printer, driver, robot, control system, a human or any other input.

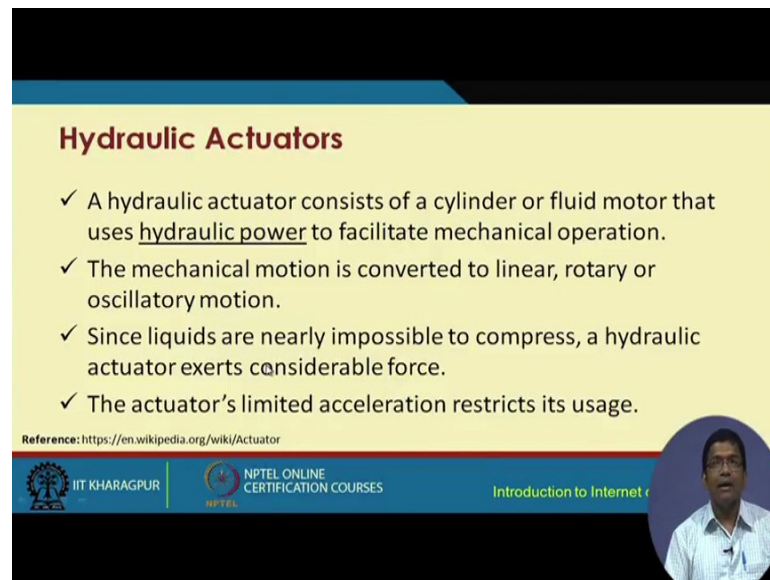
So, what we have are three types. Three types of actuators, one of actuators, one is these electric based actuators. We have this pressure based actuators and we have these mechanical based actuators. Each of these, they send control signals and based on that the actuation is going to be performed.

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So, we have hydraulic actuators, pneumatic actuators, electrical actuators, thermal actuators, magnetic actuators and mechanical actuators.

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**Hydraulic Actuators**

- ✓ A hydraulic actuator consists of a cylinder or fluid motor that uses hydraulic power to facilitate mechanical operation.
- ✓ The mechanical motion is converted to linear, rotary or oscillatory motion.
- ✓ Since liquids are nearly impossible to compress, a hydraulic actuator exerts considerable force.
- ✓ The actuator's limited acceleration restricts its usage.

Reference: <https://en.wikipedia.org/wiki/Actuator>

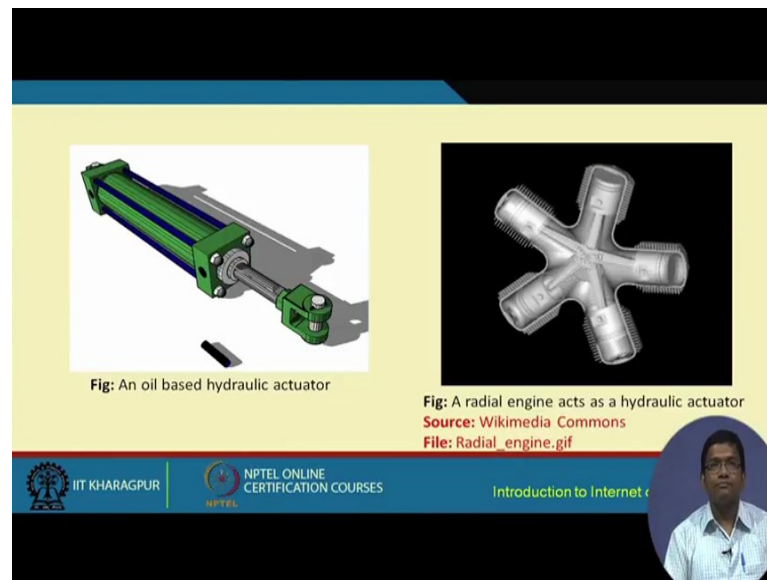
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So, this name suggests, these hydraulic actuators consist of a cylinder or fluid motor that uses hydraulic power to facilitate mechanical operation. The mechanical motion is converted to linear rotary or oscillatory motion.

So, basically you know when some fluid passes through, then you know that motion is converted to some linear motion or some oscillatory motion or rotary motion and since liquids are nearly impossible to compress, most of the hydraulic actuators basically exert considerable force. So, that is the reason why liquid based actuators are typically used you know. So, these are quite popular because of this particular reason.

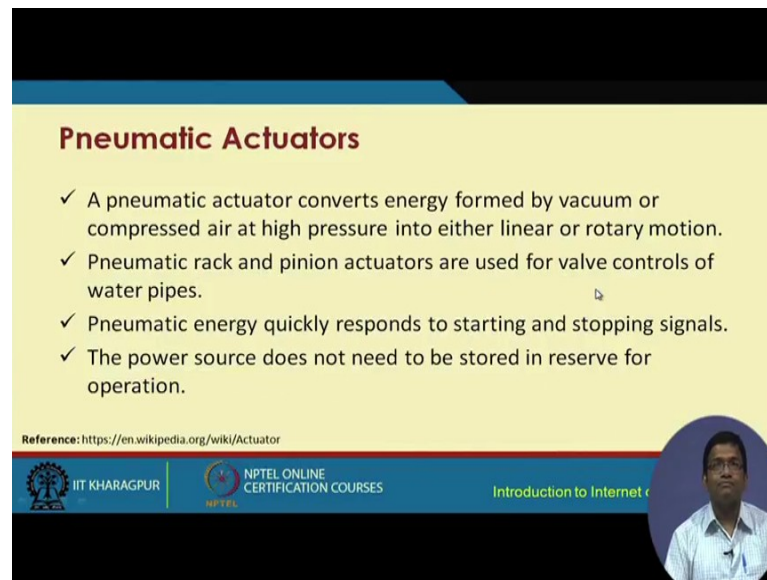
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On the left hand side, we see an example of an hydraulic actuator which is based on the use of oil. So, in this particular cylinder, oil will be there and then, when you put, when you apply pressure on it, it is going to give an output based on which there can be some linear motion or some oscillatory motion or rotatory motion or whatever that can be performed.

So, here on the right hand side, we see over here a figure which shows an hydraulic actuator based an hydraulic actuator, based on radial engine. So, as we can see over here, this is quite. This animation is quite. You know it is quite explanatory. So, as we can see over here you know liquid goes inside and when you synchronize the liquid going inside from these different directions, then what happens is you can emulate a rotatory motion like this. So, this basically can help in the functioning of an engine. So, it can give a rotatory motion in this manner.

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**Pneumatic Actuators**

- ✓ A pneumatic actuator converts energy formed by vacuum or compressed air at high pressure into either linear or rotary motion.
- ✓ Pneumatic rack and pinion actuators are used for valve controls of water pipes.
- ✓ Pneumatic energy quickly responds to starting and stopping signals.
- ✓ The power source does not need to be stored in reserve for operation.

Reference: <https://en.wikipedia.org/wiki/Actuator>

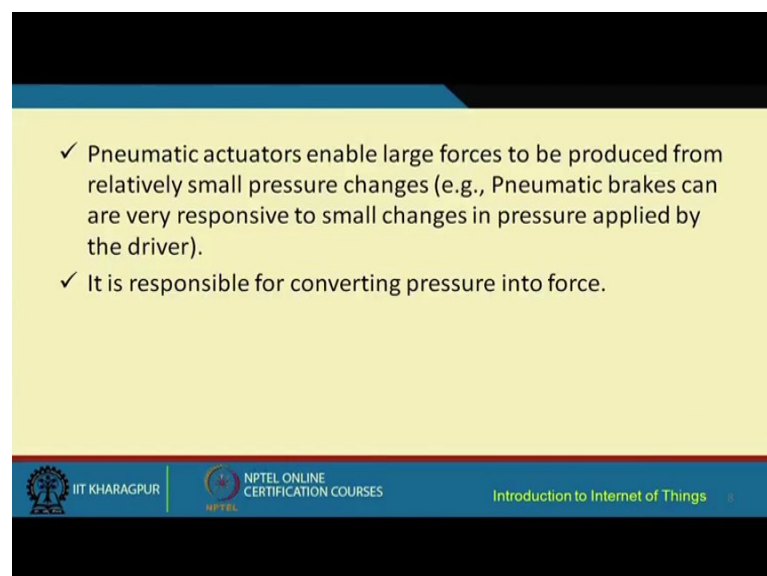
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So, those were the hydraulic actuators. Pneumatic actuator, pneumatic means air based. A pneumatic actuator basically converts the energy formed by vacuum or compressed air at high pressure into either linear or rotatory motion.

So, you know the rack and pinion actuators are typically the pneumatic actuators and these are used for valve controls of water pipe, water pipes. Pneumatic actuators basically exert a lot of force and for example, the pneumatic brakes can be very responsive to small changes in pressure that are applied by the driver.

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- ✓ Pneumatic actuators enable large forces to be produced from relatively small pressure changes (e.g., Pneumatic brakes can be very responsive to small changes in pressure applied by the driver).
- ✓ It is responsible for converting pressure into force.

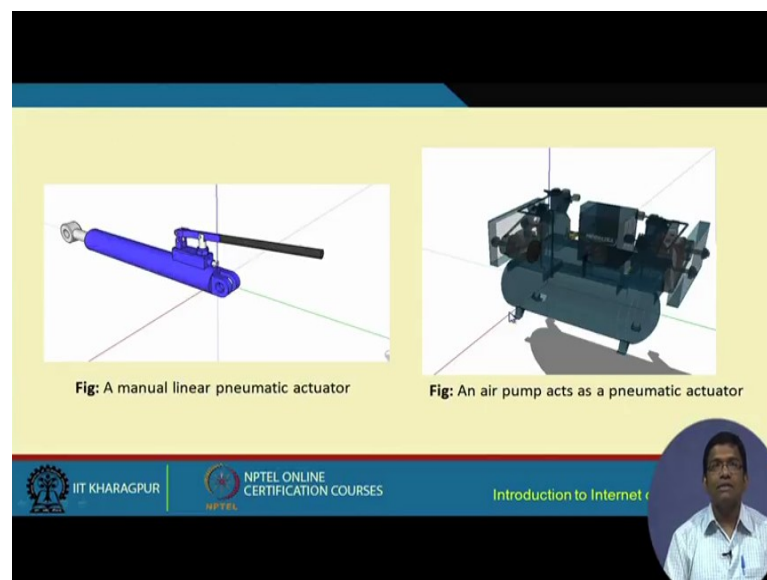
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So, pneumatic brakes are quite common in different like trucks etcetera. They use pneumatic brakes. So, hydraulic brakes are more common in cars, in trucks. The pneumatic brakes are quite common.

So, these pneumatic brakes, the advantage is that they are very responsive to small changes. You know if the action, if the brake is pressed little bit, you know they become, they act quite fast. This is an advantage of these pneumatic actuators. So, basically what happens is the pressure that is put on the brake that is converted into force pretty fast. So, this is one of the advantages of these pneumatic sensors.

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So, here is a figure of a pneumatic sensor when you apply pressure over here. So, this shaft, this crankshaft or this shaft will move and this is an example of a pneumatic actuator.

So, basically this is a figure which shows an air pump acting as a pneumatic actuator and then, we have seen hydraulic actuators, we have seen pneumatic actuators.




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### Electric Actuators

- ✓ An electric actuator is generally powered by a motor that converts electrical energy into mechanical torque.
- ✓ The electrical energy is used to actuate equipment such as solenoid valves which control the flow of water in pipes in response to electrical signals.
- ✓ Considered as one of the cheapest, cleanest and speedy actuator types available.

Reference: <https://en.wikipedia.org/wiki/Actuator>

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Then, we have the electric actuators. An electric actuator is generally powered by a motor that converts electrical energy into mechanical torque. So, this electrical energy is used to actuate the equipment, such as the solenoid valve which control the flow of water in pipes in response to electrical signals and this is what I was showing you at the outside. I showed you one of the actuators. The solenoid valve I had shown you and this basically works on the principle of electrical actuator.

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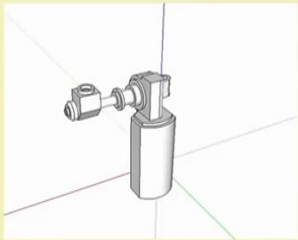


Fig: A motor drive-based rotary actuator

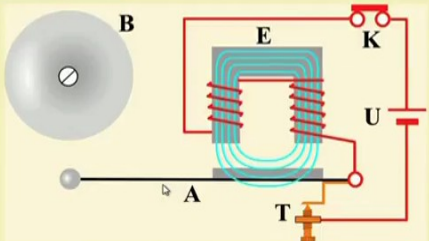



Fig: A solenoid based electric bell ringing mechanism

Source: Wikimedia Commons  
File: Electric\_Bell\_animation.gif

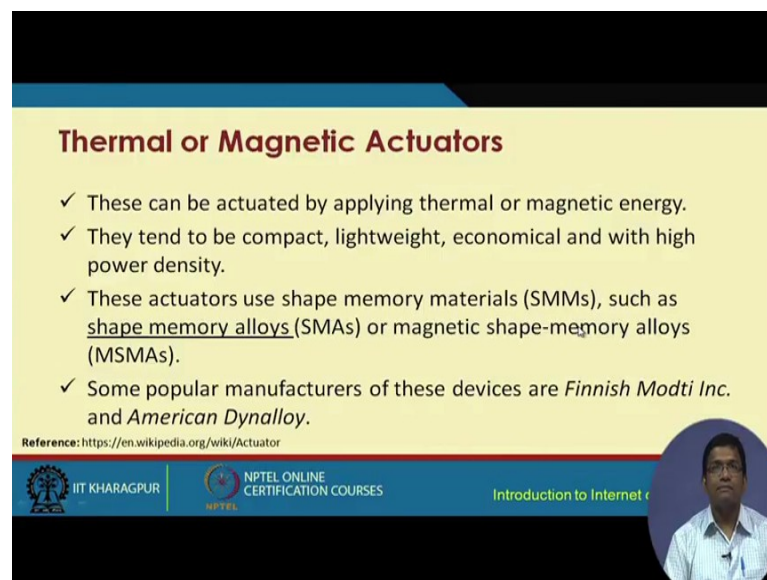
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So, on the left hand side is a figure showing a motor drive based rotary actuator. So, basically you know what happens is this basically you know the electrical signal over here will help in moving this. So, it is going to give a rotary motion of this particular part. So, this is an example of a motor drive based rotary actuator. Here in this particular animation what you see is an electric, the functioning of an electric bell. An electric bell is an example of a solenoid based actuator.

So, as you can see over here once the bell is pressed, then the connectivity is established and then, the electromagnetic field is generated due to which the bell sounds and this is the way in which solenoid based electric bells functions. So, these are two examples of electrical electrical actuators.

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**Thermal or Magnetic Actuators**

- ✓ These can be actuated by applying thermal or magnetic energy.
- ✓ They tend to be compact, lightweight, economical and with high power density.
- ✓ These actuators use shape memory materials (SMMs), such as shape memory alloys (SMAs) or magnetic shape-memory alloys (MSMAs).
- ✓ Some popular manufacturers of these devices are *Finnish Modti Inc.* and *American Dynalloy*.

Reference: <https://en.wikipedia.org/wiki/Actuator>

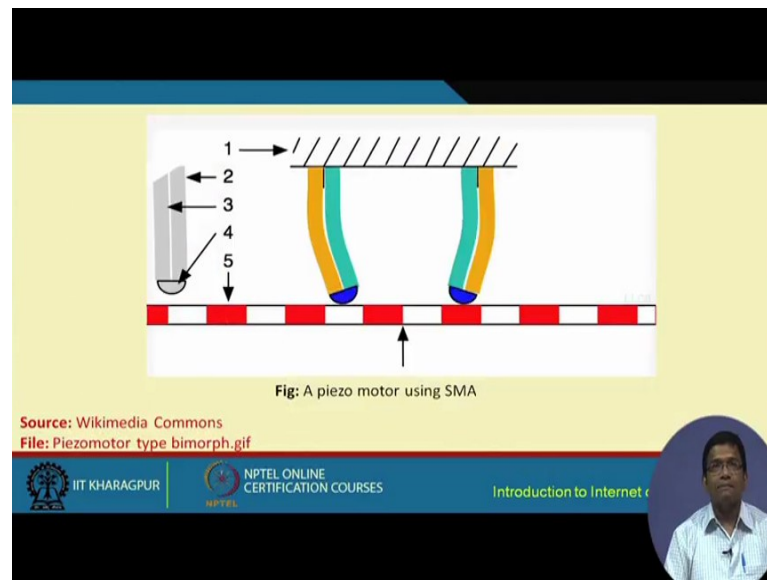
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Then, we can have thermal or magnetic actuators which can, so thermal or magnetic actuators, these can be actuated by applying thermal or magnetic energy and typically, they are very popular because of being that they are very compact, lightweight, economical and with high power density.

So, these active actuators use shape memory materials or shape memory alloys SMAs and this is very popular at present.

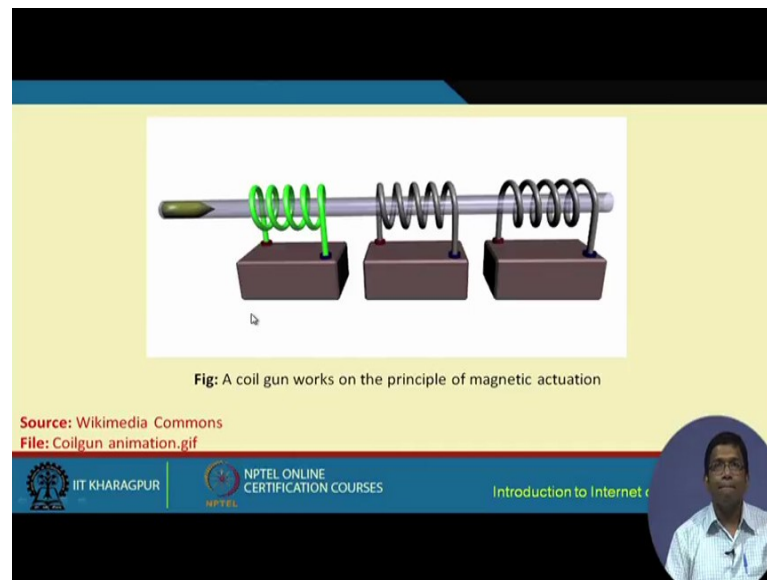
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So, this is how it works. So, this is an example of an SMA based piezo motor. So, as you can see over here, these are the different steps in which it works. So, these are two metal strips and when you know when the energy is passed through it, they bend and when they bend, they basically move this red and white strip mechanically. So, this basically acts as an actuator.

So, this is like a joint metal bar and this is like this, sorry. So, when you heat this metal bar, this is an alloy bar consisting of two metal strips. So, you know the property is that when you heat it, then it is going to bend and when it bend, it is going to move this particular strip in this manner. So, the different steps are shown over here and this is quite evident, it is quite explanatory from these steps.

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So, this is an example of a coil gun which basically works on the principle of magnetic actuation. So, this is also quite explanatory. So, this coil gun you know. So, basically you know electromagnetic field is generated and then, you know again it is pushed and so on.

So, basically you know functioning of the hyper loops, at present people are talking about hyper loops, right. So, presenting if the functioning of the hyper loops are also you know based on this particular principle.

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### Mechanical Actuators

- ✓ A mechanical actuator converts rotary motion into linear motion to execute some movement.
- ✓ It involves gears, rails, pulleys, chains and other devices to operate.
- ✓ Example: rack and pinion.




Fig: A rack and pinion mechanism  
Source: Wikimedia Commons  
File: Rack and pinion.png

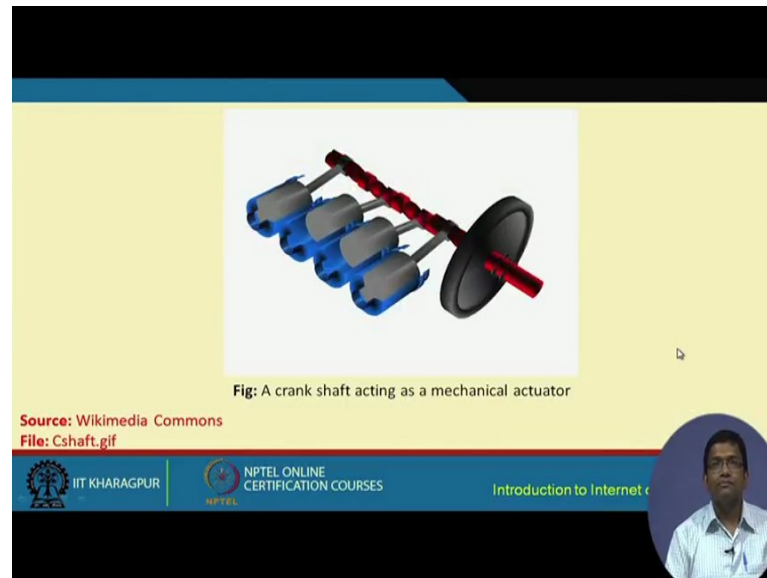
Reference: <https://en.wikipedia.org/wiki/Actuator>

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The slide is titled 'Mechanical Actuators' in bold red text. It contains a bulleted list of three points describing mechanical actuators. To the right of the list is a 3D rendering of a rack and pinion mechanism, showing a circular gear (pinion) meshing with a straight-toothed gear (rack). Below the diagram is a caption and source information. The slide footer includes the IIT Khargapur and NPTEL logos, the course title 'Introduction to Internet of Things', and a small circular inset photo of a man in a blue shirt.

Then, we have these mechanical actuators which basically convert rotatory motion into linear motion to execute some movements. So, this basically involves these gears, the pinions, gears, pinions rails, pulleys, chains and other devices to operate. So, rack and pinion is an example of a mechanical actuator. The figure shows it and it is quite exponentially from this.

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So, as it moves, basically this also moves. So, a crankshaft is another example of a mechanical actuator. So, this is how the crankshaft works.

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### Soft Actuators

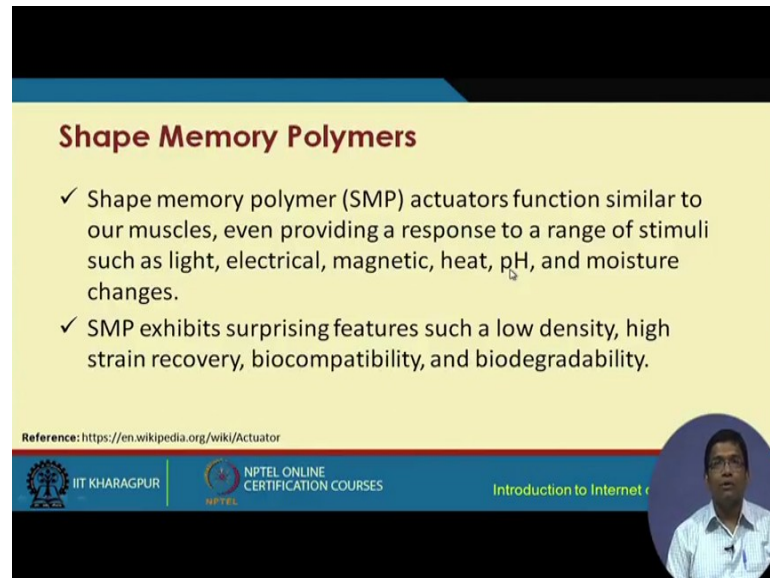
- ✓ Soft actuators (e.g. polymer based) are designed to handle fragile objects like fruit harvesting in agriculture or manipulating the internal organs in biomedicine.
- ✓ They typically address challenging tasks in robotics.
- ✓ Soft actuators produce flexible motion due to the integration of microscopic changes at the molecular level into a macroscopic deformation of the actuator materials.

Reference: <https://en.wikipedia.org/wiki/Actuator>

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So, as this thing moves in this manner, so this gives this one a mechanical motion, a rotatory motion. There are different soft actuators which are actually polymer based and the design to handle fragile objects like fruit harvesting in agriculture or in biomedicine, handling internal organs of human beings and typically these are used in robotics. So, soft actuators are also quite popular.

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**Shape Memory Polymers**

- ✓ Shape memory polymer (SMP) actuators function similar to our muscles, even providing a response to a range of stimuli such as light, electrical, magnetic, heat, pH, and moisture changes.
- ✓ SMP exhibits surprising features such as low density, high strain recovery, biocompatibility, and biodegradability.

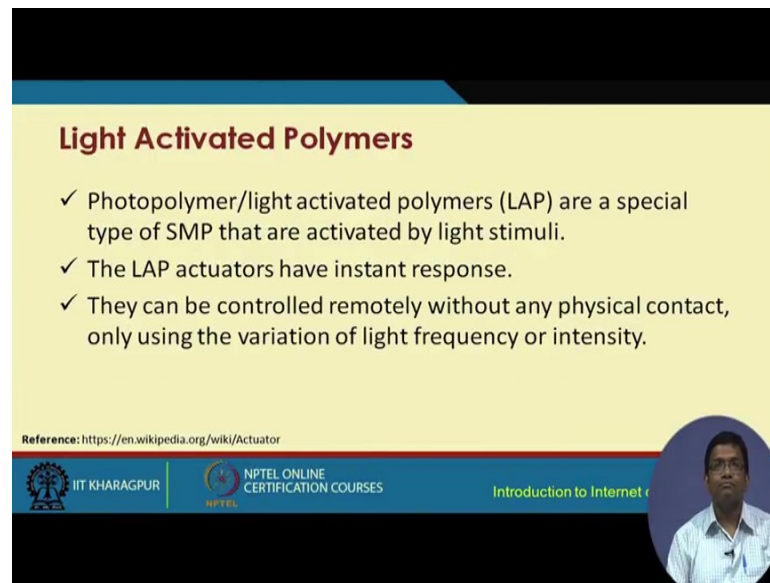
Reference: <https://en.wikipedia.org/wiki/Actuator>

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The slide features a yellow background with a blue header and footer. A small circular inset in the bottom right corner shows a man in a blue shirt speaking.

These basically use something known as SMP, the Shape Memory Polymers which are actually polymers and the behavior of the polymers will change depending on the stimuli. The stimuli for these polymers are the light, electrical signals, magnetic signals, heat, PH etcetera. They have different properties. These polymers, they behave differently due to these different variations in these physical properties.

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**Light Activated Polymers**

- ✓ Photopolymer/light activated polymers (LAP) are a special type of SMP that are activated by light stimuli.
- ✓ The LAP actuators have instant response.
- ✓ They can be controlled remotely without any physical contact, only using the variation of light frequency or intensity.

Reference: <https://en.wikipedia.org/wiki/Actuator>

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Then, we have the light activated from polymers. These polymers basically get activated through light stimuli and these are also quite popular. So, what we have seen are different actuators, their actuation principles and different diagrams and figures of them and at the outset, we have already seen some real actuators that can be used for building IoT based systems.

Thank you.