Chemical Process Instrumentation

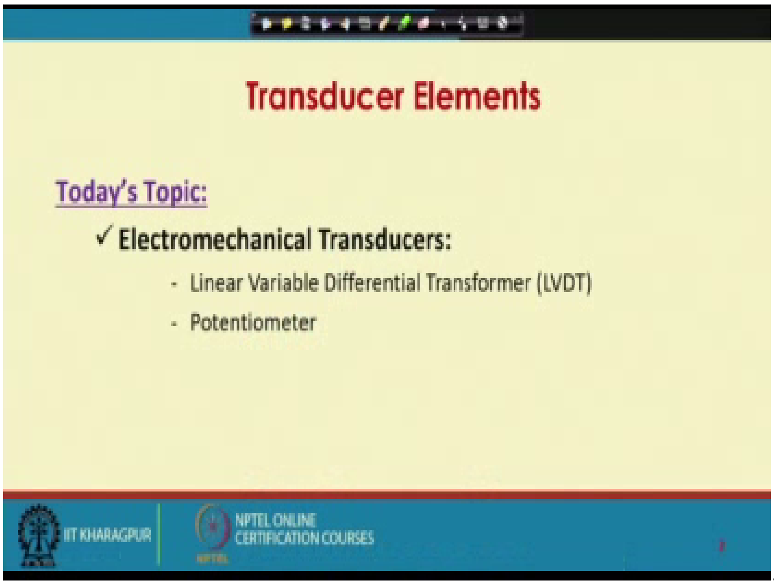
Prof. Debasis Sarkar
Department of Chemical Engineering
Indian Institute of Technology, Kharagpur

Lecture – 17
Transducer Elements (Contd.)

Welcome to lecture 17, we have started our discussion on transducer elements in our previous lecture we have talked about flapper nozzle systems, we have also talked about classification of various transducer elements, we are broadly classified them under 2 categories pneumatic transducer and electromechanical transducers these are the two types of transducer that we will talk about, pneumatic transducers we have talked about in the previous lecture, so we have talked about flapper nozzle systems as an example of pneumatic transducers.

In this lecture, we will talk we will start our discussion on electromechanical transducers. Essentially we will be talking about something called linear variable differential transformer which is an; electromechanical transducers, we will also briefly talk about potentiometer which also works as a transducer, both are displacement both receives displacement as input and gives us electrical signal as output.

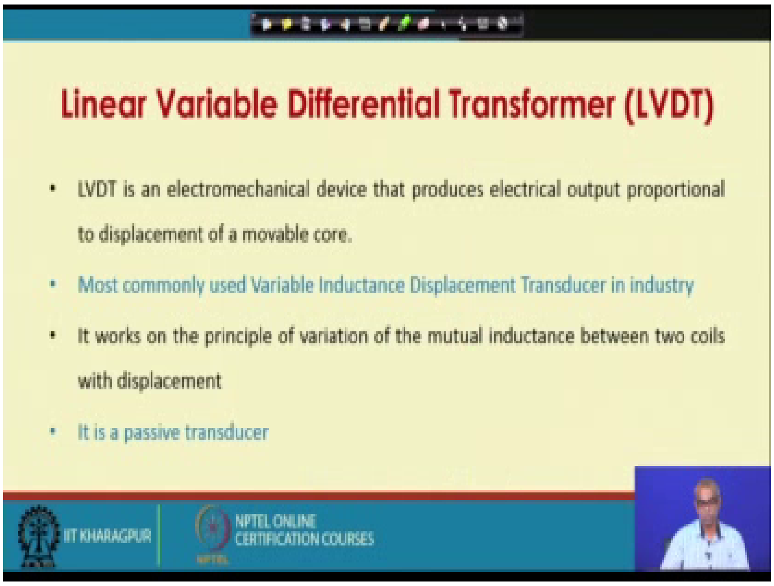
(Refer Slide Time: 01:34)



.

So, today's topic is electromechanical transducers. We will talk about linear variable differential transformer or LVDT and a potentiometer.

(Refer Slide Time: 01:45)

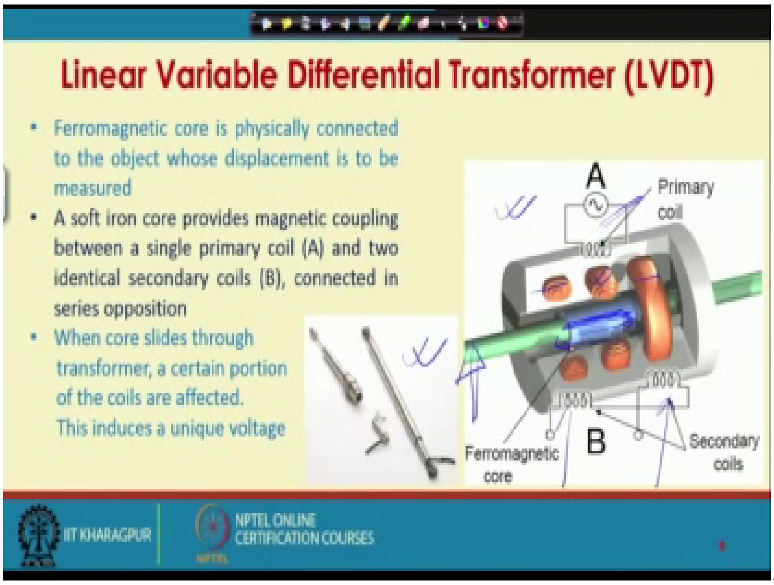


Linear variable differential transformer or LVDT is an electromechanical device that produces electrical output proportional to displacement of a movable core. So, the displacement of a movable core gives the displacement input to the LVDT and in detail LVDT gives us an electrical signal as output.

LVDT is the most commonly used variable inductance displacement transducer in industry. So, this is a variable inductance type transducer and this is also a displacement measuring transducer, LVDT works on the principle of variation of the mutual inductance between two coils with displacement. LVDT is a passive transducer, if you remember we had classified instruments as active as passive, so an active transducer and a passive transducer LVDT is an example of a passive transducer.

Linear variable differential transformer or LVDT looks as shown on the screen. So, it consists of two coils; one primary coil and two secondary coils which are connected in series.

(Refer Slide Time: 03:17)

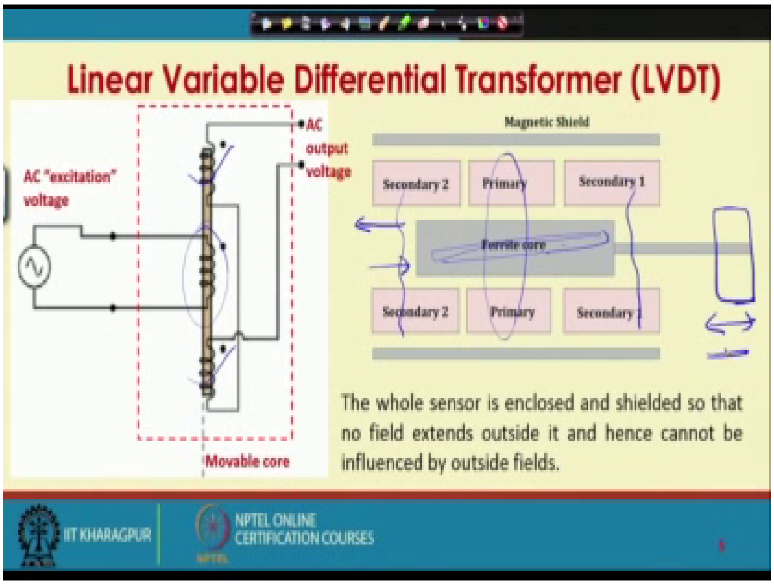


Now, a ferromagnetic core is physically connected to the object whose displacements is to be measured, a soft iron core provides magnetic coupling between the single primary coil and two identical secondary coils which are connected in series opposition, when the core slides through transformer a certain portion of the coils are effective this induces a unique voltage. So, this is LVDT; so inside you are expected to see this, you have a primary coil and you have two secondary coils which are connected in series opposition.

Now you have this soft iron core, which provides the coupling between the primary coil and the secondary coils. Now, the object whose displacement needs to be measured is physically connected to this core, so we can connect the object whose displacement needs to be measured, now with the motion of the object this core will have a movement. So, this core will either go in this direction or will come in this direction, so a certain portion of the coils will be affected.

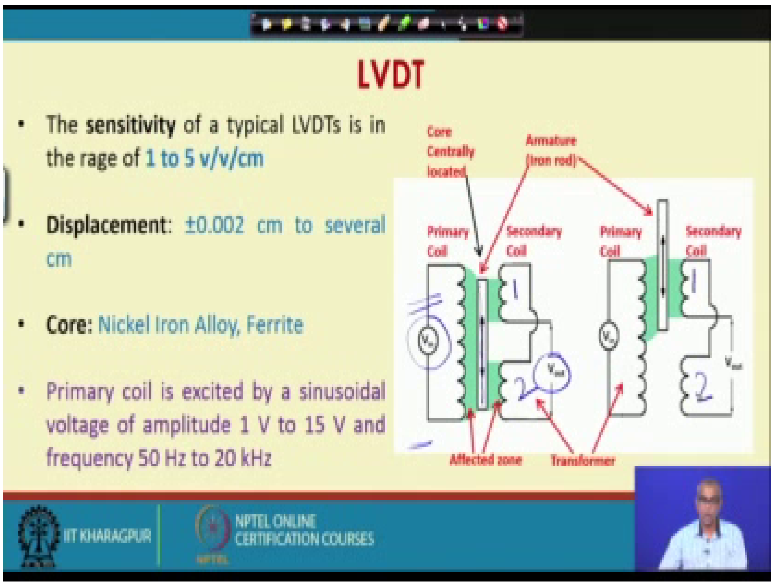
And this will induce a unique voltage and this voltage is proportional to the displacement, this will be more clear if you take a look in another figure. So, you have primary coil and you have two secondary coils connected in series opposition primary coil secondary coils.

(Refer Slide Time: 06:28)



Now, so this is the soft iron core or ferrite core that provides magnetic coupling between this primary coil and the secondary coils, this core is connected to the object whose displacement needs to be measured, so this object is physically connected to this ferrite core. So, as this object shows displacement this ferrite core will be moving in this direction or in this direction, so different part of the coils will be affected and that will produce different voltage, thus voltage is proportional to the displacement of the object. The whole sensor may be enclosed and put inside a magnetic shield so that no field extent outside it and hence cannot be influenced by outside fields.

(Refer Slide Time: 08:44)



This figure clearly explains; the working of the LVDT, you have a primary coil and you have two secondary coils connected in series opposition. So, this is the iron core this will be connected directly to the object whose displacement needs to be measured, so this soft iron core will be connected with a moving object. In this figure; this soft iron core is centrally located, so the coils are equally affected. The primary coil is excited by this voltage, now when this prime when this soft iron core is centrally located these two secondary coils are equally affected, these two secondary coils are identical they are connected in series opposition.

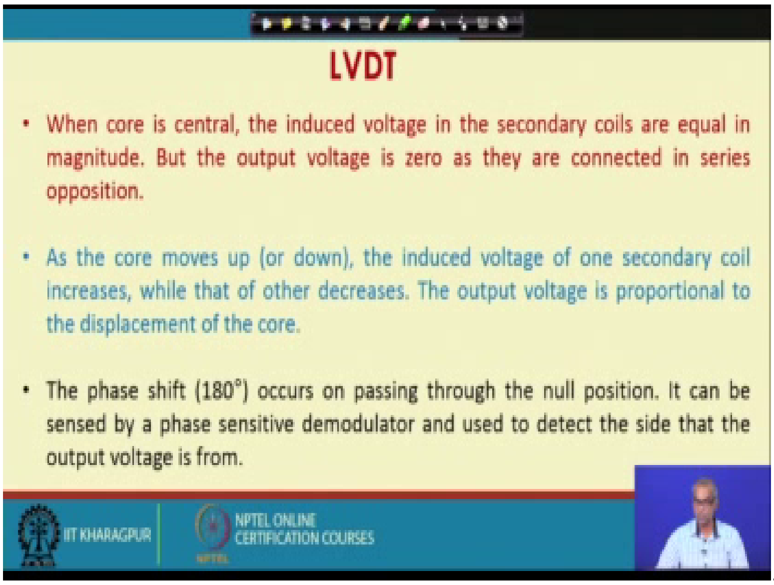
So, when these two secondary coils are equally effected, equal amount of voltage is induced in these two secondary coils, but since these two coils are connected in series opposition the output voltage; which is, the difference between say the voltage V 1 minus voltage V 2 will be equal to 0. Now when this soft iron core is not centrally located let us say; it is pushed up, so only this secondary coil number 1 is affected secondary coil number 2 is not affected. So, the output voltage will no longer be I no longer be 0, it will be the difference between voltage V 1 and voltage V 2.

So, when the soft iron core is centrally located the output voltage will be 0, but when the soft iron core is not centrally located there will be a nonzero voltage output from the secondary coils, so this output voltage is a measure of the displacement. The sensitivity of a typical LVDT is in the range of 1 to 5 volt per volt per centimeter, the displacement that can be measured may be very small that is plus minus .002 centimeter to several centimeters, it is reported as on both sides of the midpoint or null point.

The core is made of nickel iron alloy or ferrite most commonly, primary coil is excited by a sinusoidal voltage of amplitude 1 volt to 15 volt and frequency 50 hertz to 20 kilohertz.

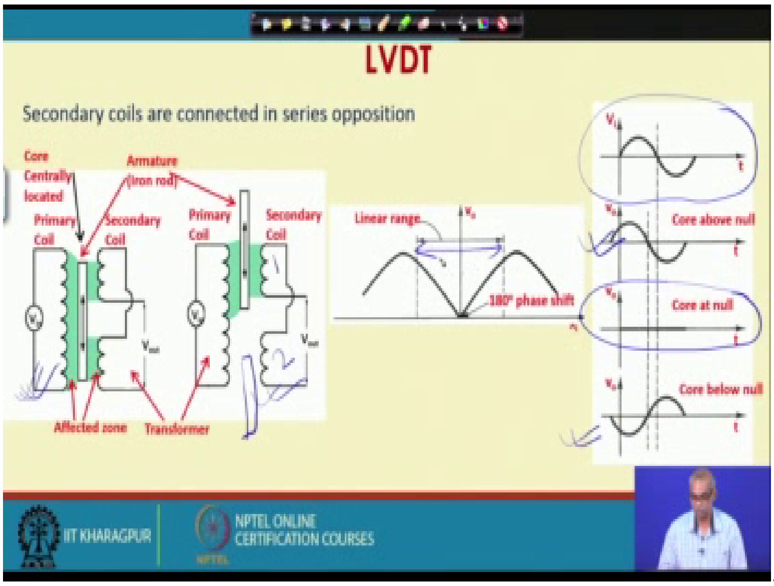
When core is central the induced voltage in the secondary coils are equal in magnitude, but the output voltage is 0 as they are connected in series opposition, as the core moves up or down the induced voltage of one secondary coil increases while that of other decreases the output voltage is proportional to the displacement of the core.

(Refer Slide Time: 13:33)



The phase shift of 180 degree occurs on passing through the null position, null position is? When the core is centrally located, so equal amount of voltage is induced in the secondary coils and the net output is 0. The phase shift of 180 degree occurs on passing through the null position, these phase shift can be sensed by a phase sensitive demodulator and used to detect the side that the output voltage is from. So, from which side these output voltage is coming can be detected by a phase sensitive demodulator.

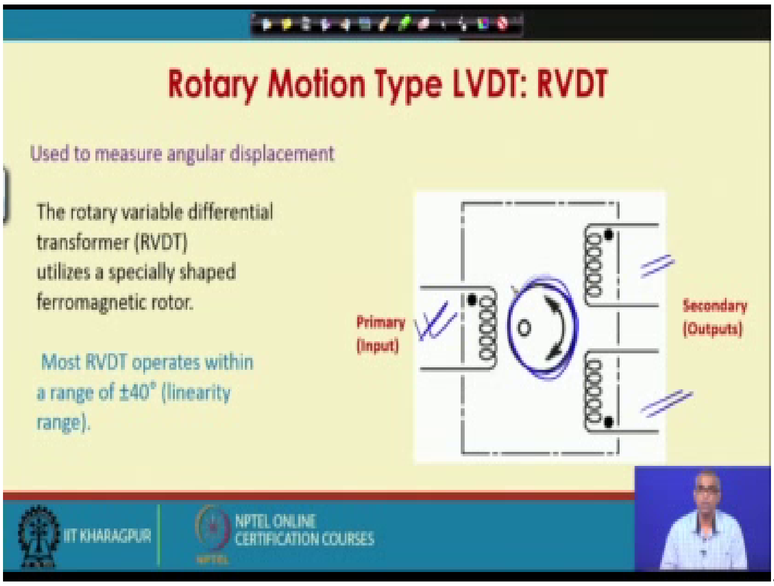
(Refer Slide Time: 14:41)



So, this figure shows how this phase shift occurs? Here the core is centrally located, so the output voltage is 0, so this is core at null. Whereas here the core has been pushed up such core is above null, so it shows a non 0 voltage, the core can be here as well below null and then this secondary coil 1 will not be affected, but secondary coil 2 will be affected.

Now let us say I am giving this sinusoidal voltage as input, when the core is centrally located or core is at null my output voltage is 0, so my graph will output voltage by time graph will be like this, but when is core above null or core is below null will have a non 0 voltage, but look at the plot for core above null and then look at the plot for code below null both are sinusoidal, but there is 180 degree phase shift. So, there is a linear range for this instruments working.

(Refer Slide Time: 16:52)

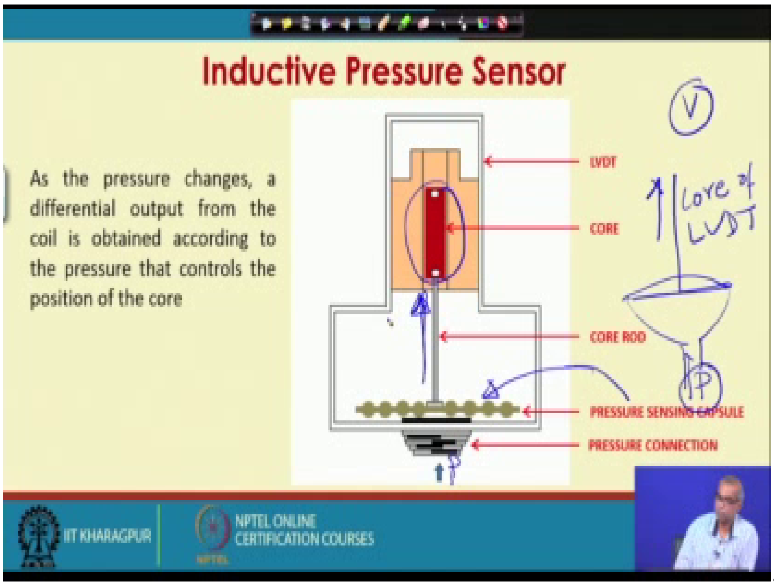


There is a rotary motion type LVDT known as RVDT full form is rotary variable differential transformer, the rotary variable differential transformer or RVDT is used to measure angular displacement. The rotary variable differential transformer or RVDT utilizes a specially saved ferromagnetic rotor, most RVDT operates within a range of plus minus 40 degree and this is the linearity range of the RVDT.

So, it is very much similar to linear variable differential transformer or LVDT you have the primary coil, you have two secondary coils which are connected in series opposition, now this is the score is specially shaped ferromagnetic rotor which may be connected to the object which shows rotary motion.

So, the angular displacement can be measured the object which is in a angular motion will be connected to this specially shaped ferromagnetic rotor and the rest of the working is similar to linear variable differential transformer.

(Refer Slide Time: 19:02)

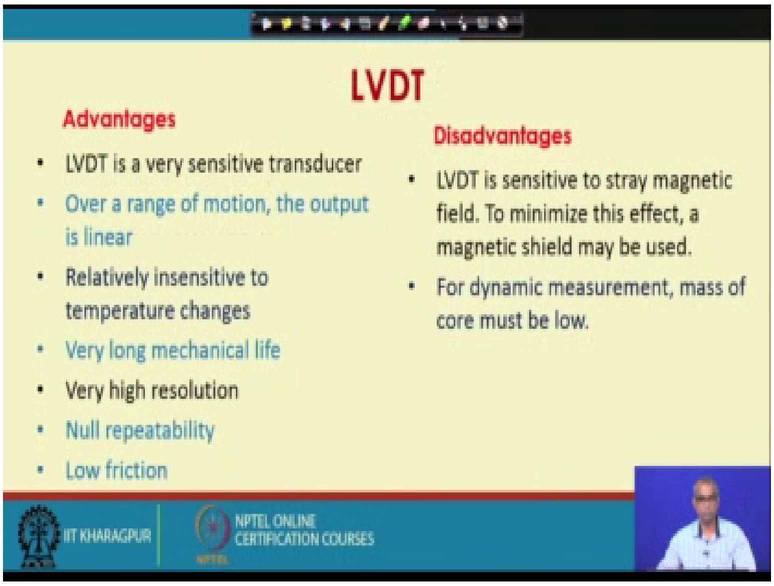


Let us look at; the inductive pressure sensor, this uses a linear variable differential transformer or LVDT. The inductive pressure sensor is basically a pressure transducer, so it receives pressure as input signal and gives us an electrical signal as a output, the pressure sensing element is called capsule. A capsule is formed from several diaphragms, to understand the working of these phases sense pay inductive pressure sensor you can also consider the pressure sensing capsule as a simple diaphragm, to this diaphragm I have attached the core of LVDT; now, I applied pressure inside this pressure works on this diaphragm, so the diaphragm will deflect if the diaphragm deflects the core will move off, so that displacement will cause LVDT to give a voltage as an output. So, this pressure will be related to the output voltage from the LVDT.

So, as the pressure changes our differential output from the coil is obtained according to the pressure that controls the position of the core. So, this pressure sensing capsule receives pressure accordingly it deflects, that displacement goes through these core of the LVDT and the location of this LVDT core is decided by this displacement. Accordingly an appropriate voltage from the LVDT will be produced depending on the portions of the secondary coils that are affected.

So, the pressure that is being applied to this diaphragm or process sensing capsule can be related to the output voltage from the LVDT. So, this is how an inductive pressure sensor will work.

(Refer Slide Time: 23:02)

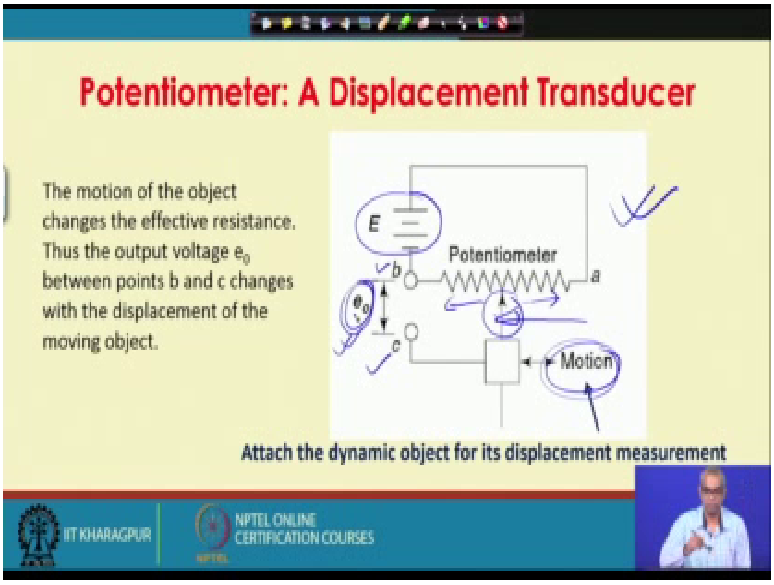


Let us now list out the advantages and disadvantages of LVDT. LVDT is a very sensitive transducer over a range of motion the output is linear, LVDT is relatively insensitive to temperature changes, it has a very long mechanical life, it has very high resolution, null repeatability is there, it also shows low friction, there are several advantages of LVDT disadvantages are not that significant.

As explained earlier LVDT may be sensitive to stray magnetic field, to minimize this effect of outside magnetic field or stray magnetic field a magnetic shield may be used. So, LVDT may be enclosed by a magnetic shield to protect it from the effect of stray magnetic field or outside magnetic field.

We have to keep in mind that for dynamic measurements mass of LVDT core should be low, and then it will be convenient for dynamic measurements. Potentiometer can also be used as a displacement transducer; the figure shows a schematic for a potentiometer.

(Refer Slide Time: 25:00)



So, this is the exciting voltage and let us says; the object whose displacement of motion is to be measured is connected to this arm. So, with the motion or displacement of the moving object these are moves in this direction or in this relation, so the motion of the object changes the effective resistance, the motion of the object fixes the position of the arm and that fixes the effective resistance, thus the output voltage e 0 between point's b and c changes with the displacement of the moving object.

So, the output voltage e 0 is a measure of the displacement of the moving object. So, the moving object is connected to this arm as this moving object shows displacement the arm takes a particular position that determines the effective resistance that determines the output voltage. So, the motion of the object changes the effective resistance, thus the output voltage e 0 between point's b and c changes with the displacement of the moving object, so potentiometer behaves like a displacement transducer. So, we will stop our lecture 17 here, so we talked about two displacement transducers LVDT and potentiometer, in the next lecture, we will talk about other types of electromechanical transducers.