Mechanical Measurement Systems
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Lecture – 25
Transducers (1)

Hello, I welcome you all in this course of mechanical measurement systems. Today, we shall start with the transducers.

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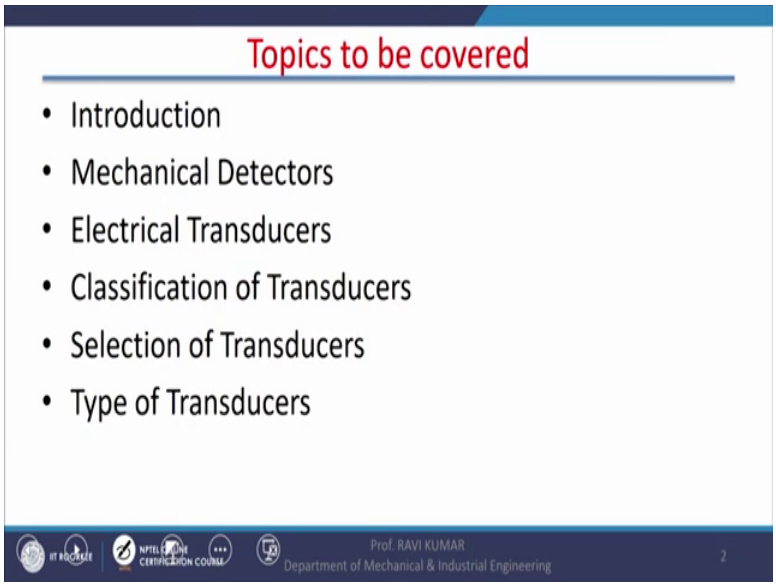

Topics to be covered today are first I will give you introduction of the transducers. Then there are certain mechanical detectors which are used in transducers, electrical transducers, then we will do classification of transducers, selection of transducers and we will discuss different type of transducers.

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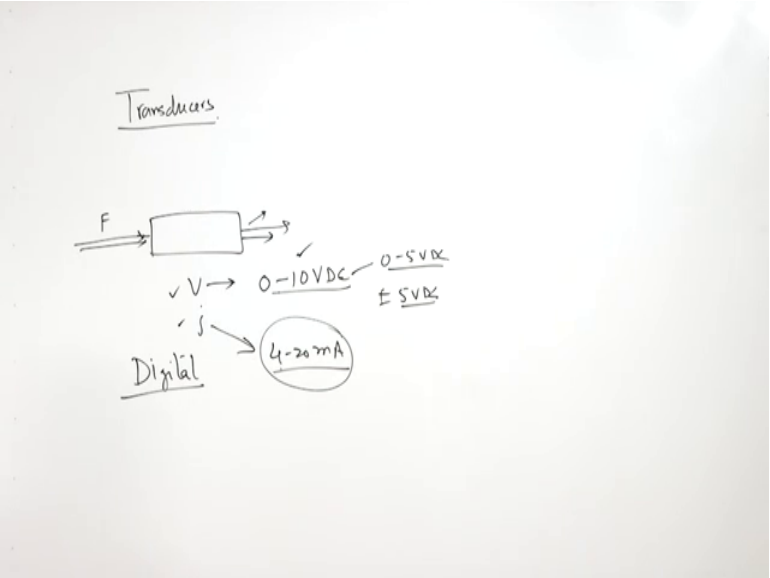

So, to the begin with introduction and definition of transducers. Now, transducers transducer is a device which is used for converting one form of energy into another form of energy. There is a very broad definition of transducers. The certain amount of energy is giving suppose some force is applied and some displacement is taking place, right. So, this energy due to this force and displacement F x is going to the transducer and then it is converting in different type of energy or normally nowadays the output of the transducers are in the form of electrical signals. Electrical signals may be in the form of voltage or in the form of current.

Now, the output in voltage normally it is in the range of 0 to 10 volt DC normally. In some of the transducers it is 0 to 5 volt dc or plus minus 5 volt DC or the output in the transducers is in the range of 4 to 20 milliamperes. Even when the signal has to be transmitted for a far off distance suppose we are acquiring data in this room and data has to be transmitted somewhere 100 meters away or 50 meters away from this room in that case normally this current type of output is preferred, because if we go for the voltage type of output voltage drop may take place in wire also and that will change the actual output.

So, nowadays it is also defined transducers are also defined in a device which converts which take certain amount of input and the input is converted into the electrical signals, right and normally electrical signals are in the form of voltage and current and signals are

normally in digital form or after transmission they are converting into converting into the digital form.

Because, the data acquisition at the time of acquiring the data because all these signals will be going through a data acquisition system and in a data acquisition system the signals are stored in a digital form so that you can transfer those signals to other systems in the digital form taking this data in a in a pen drive or CD or in a floppy.

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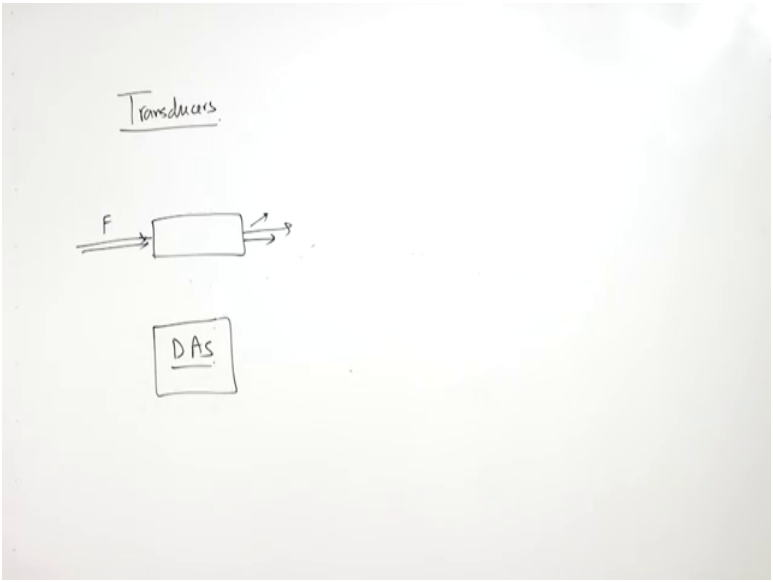

So, now transducers be contain a primary sensing element also or they may not contain a primary sensing element. Second thing is sometimes the output of the transducer is very weak, it is feeble output.

So, this output has to be amplified or increased. So, for the amplification purpose if it is a electrical signal we can use amplifiers can be very well used and feeble signal can be converted into a power powerful signal mechanical signals also can be amplified for example, there is a change in the level you are just connect you are just connecting what phenomena with the change of the level of the water.

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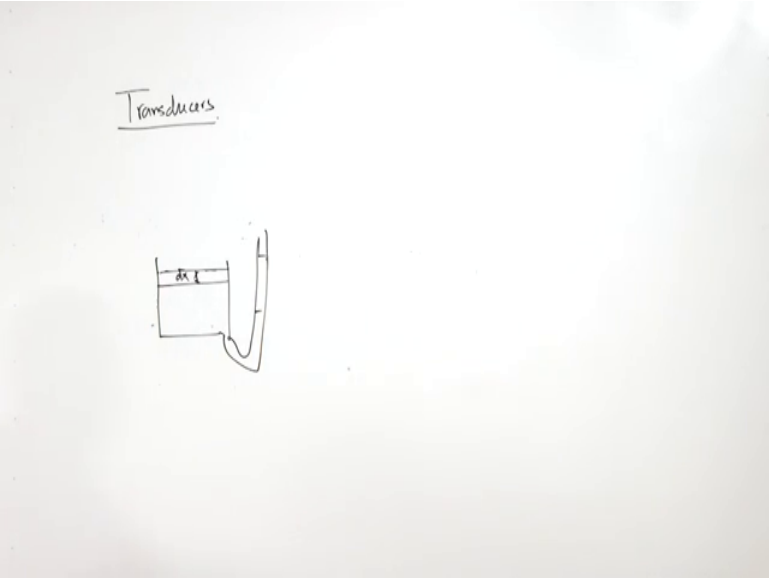

Now, this change in level of the water dx can be enhanced by just putting this water in connecting a tube right. So, whatever change is taking place here, but it will be in the vertical direction. So, whatever change in volume is there not in dx, whatever change in the volume is there here you can very well or accurately measure the volume. So, that is another way of enhancing the output signal. Third way we can be like you can use lever theta suppose there is a displacement theta and you are measuring theta with certain displacement dx.

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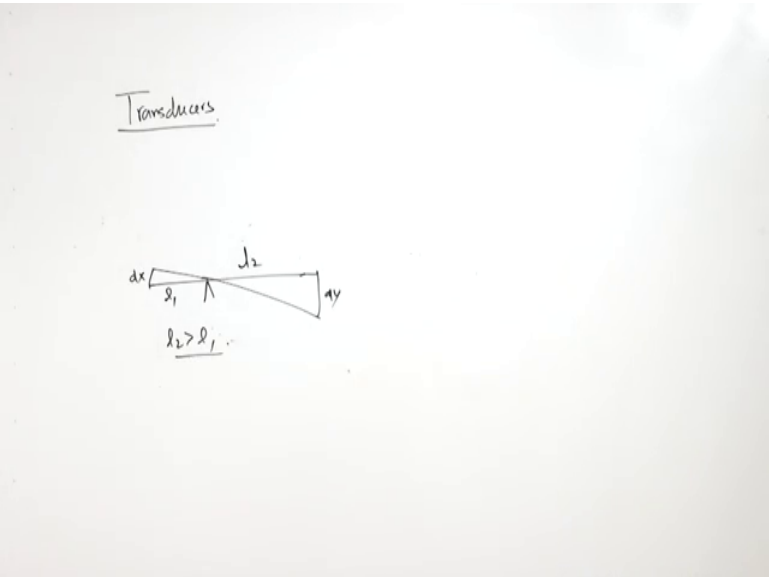

So, this principle you can always enhance this dx to dy if this l 2 is greater than l 1. So, amplification of signal is also important it is often being done in the case of transducer. So, first of all the measurement in the in the content of the measurement comes the transducer itself in most of the cases it is transducer which comes into the context of measurement for example, thermocouple for example, pressure gauge, right.

So, pressure gauge this is transducer, right, which convert pressure into the deflection of the needle by certain angle. So, it is a sort of a transducer thermocouple is a transducer because it converts temperature into the EMF and these transducers they also come into contact with the measurement and in the process of measurement certain amount of energy is drawn from the measurement. This I have already explained earlier in the process of measurement certain amount of energy is drawn from the measurement.

So, this energy has to be minimum for well design transducers actually transducers should not draw any energy for the measurement, but without withdrawing energy the measurement process is not possible. So, transducer should draw I mean good well design transducer should draw minimum energy from the measurement and nowadays most of the signals or output from the transducer is in the form of electrical signals and electrical signals are or normally voltage are in the form either in the form of voltage or in the form of current.

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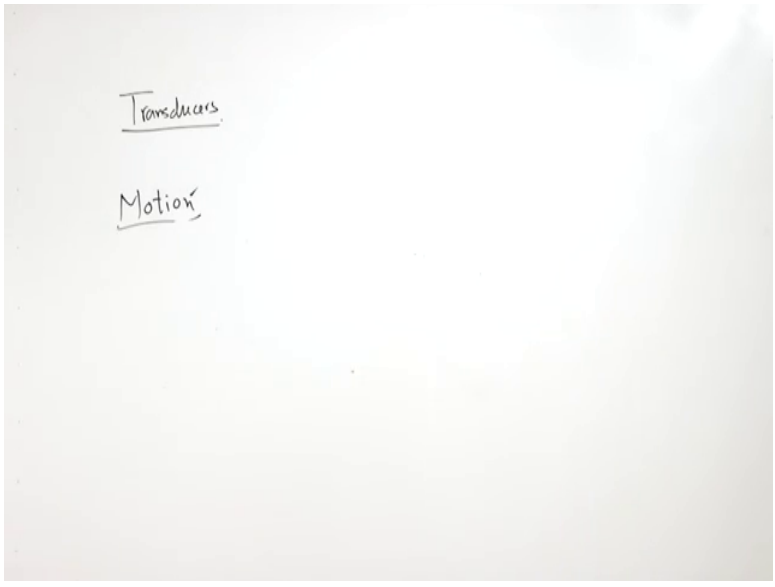

Now, while we are selecting a transducer normally I am talking about the mechanical transducers. In mechanical transducers the output is normally in the form of motion the output of the transducer is normally. In the form of motion it may be a linear motion or it may be an angular motion now the certain things are to be kept in mind while choosing a transducer if for a mechanical system that is magnitude of the motion. What is the magnitude of the motion because once you know the magnitude of the motion you can identify the quantity of error also in the measurement, right.

So, definitely if the magnitude is not much the amplifiers are used to amplify the the motion so that error in the measurement is reduced and while going for the transducer we should know of obviously, we should know for input output relationship.

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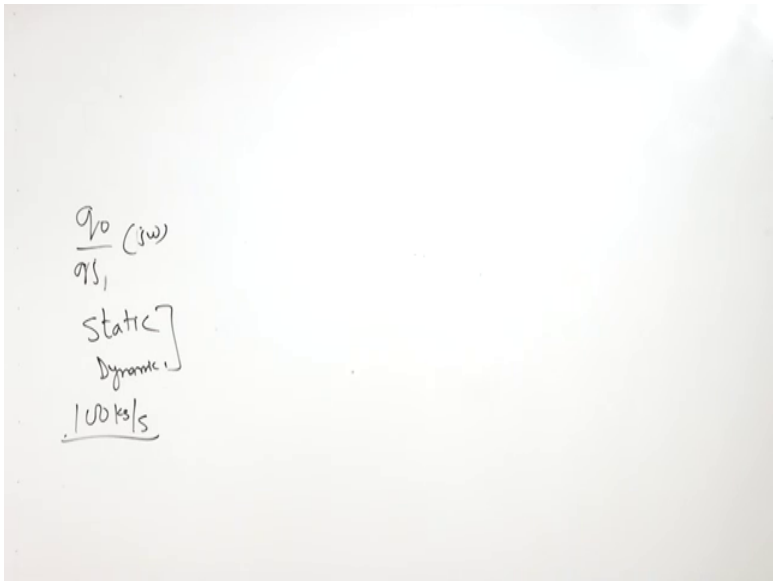

The input output relationship means q upon qi either in for transient input or for a cyclic input. So, output and the input relation has to be known while going for the transducer.

Now, static now again the it follows by a static and dynamic characteristics of the transducer, especially when the when the there is a time variant signal when there is a time variant signal the dynamic characteristics have becomes very important and because nowadays we have digital storage system.

So, a storage is not a problem for us, earlier a storage was a problem I mean there many other mechanical devices where the recorder type of devices were used chart recorder

type of like devices were used for the storage of data. But, nowadays we have digital storage system and that is very convenient for a storage of data and very easily we can go for let us say 100 kilo samples per second such type magnitude of data acquisition we can go for if we have appropriate data acquisition system.

Now, attachment type or proxy type some of the transducers do not come in contact with the measurement physically they are not in contact with the measurement. So, such type of transducers are known as proximity sensors or proxy type of transducers.

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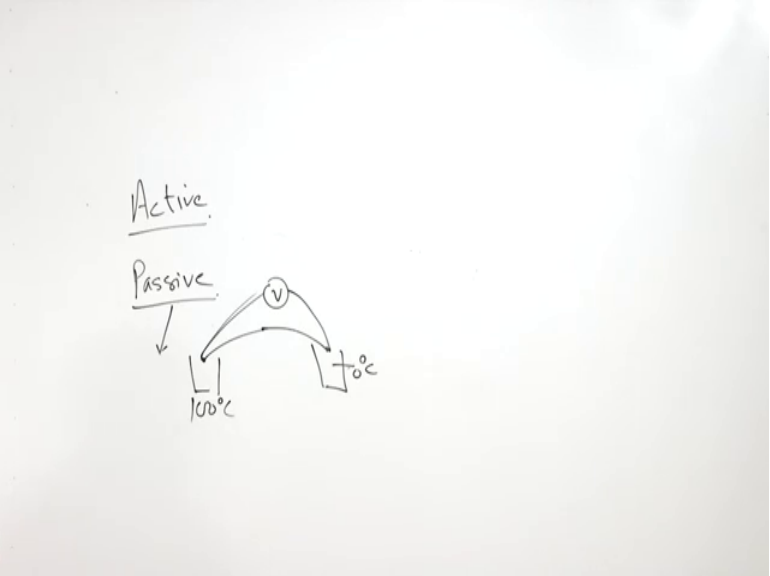

And, the third one is and the last one is active transducer and passive transducer and passive. Now, passive transducers are those transducers which do not require any external source of energy, right. Simply you put the transducers no power input is required for example, thermocouples are one of the such transducers which do not require any external source of energy simply one end thermocouple you can put on the measurement and other end either you connect to the data it depends upon the type of data acquisition system you are using.

If you are using a modern data acquisition system immediately the wires can go to the data acquisition system if you are using the voltmeter in that case this side has to be in 0 degree centigrade and voltmeter will you takes somewhere here right, but nowhere it is drawing energy from extra it is standalone system it is not trying any other energy from

the outside source simply one end is at higher temperature let us say 100 degree centigrade this is melting ice at 0 degree centigrade melting ice of distilled water.

Now, EMF is generated we will measure the EMF they are calibration charges for a particular EMF we can find the value of temperature and we can see whether it is a 100 degree or 99 degree or 101 degree, but no external source of energy is required.

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However, in the case of let us say pressure transducers in pressure transducers for measuring the pressure external source of energy is required normally the source of energy varies from 12 to 24 volt DC. Normally it is not necessarily, but normally it varies from 12 to 24 DC supply and this excitation voltage what it does it benefice the it activates the primary sense in and at the same time it magnifies the output of the transducer.

So, there two types of transducers active transducer and passive transducer. So, passive transducer does not take any source of external energy active transducers try to do take external source of energy, right. So, there is another way of classification on the transducer and we have to choose for a particular application which type of transducer will be suitable.

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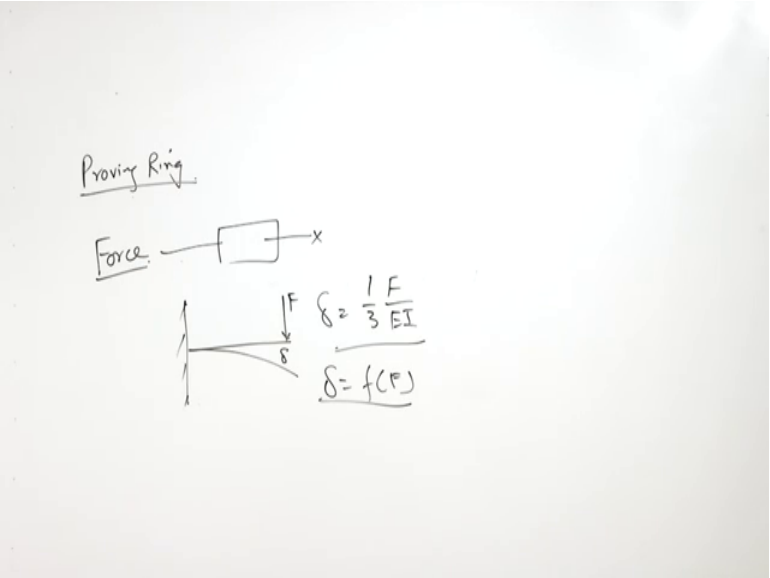

Now, there certain mechanical detectors for example, for displacement there is a detector proving ring. Proving ring is used for measurement of force. So, input signal is force, but we cannot see force; force cannot be seen. So, first of all the function of the transducer is to give the output in a in to change the phenomena or to give the output in the measurable quantity. Force we cannot measure, we can determine force mass into acceleration, right. For measuring the force for measuring the force a transducer is used and this force will be converted into the displacement, right.

So, how we can do that they are several techniques simplest one you take one cantilever and just apply force here, whatever the displacement is there delta and delta and force relationship is also known to us that is delta is equal to 1 upon 3 EI sorry 1 upon 3 F over EI.

So, delta is a function of F that is one way. I mean there can be several ways I mean and the most popular or establish way of measuring force is proving ring, but the proving ring we can go for a small amount or medium amount of force small on medium forces. For very large force it is not recommended.

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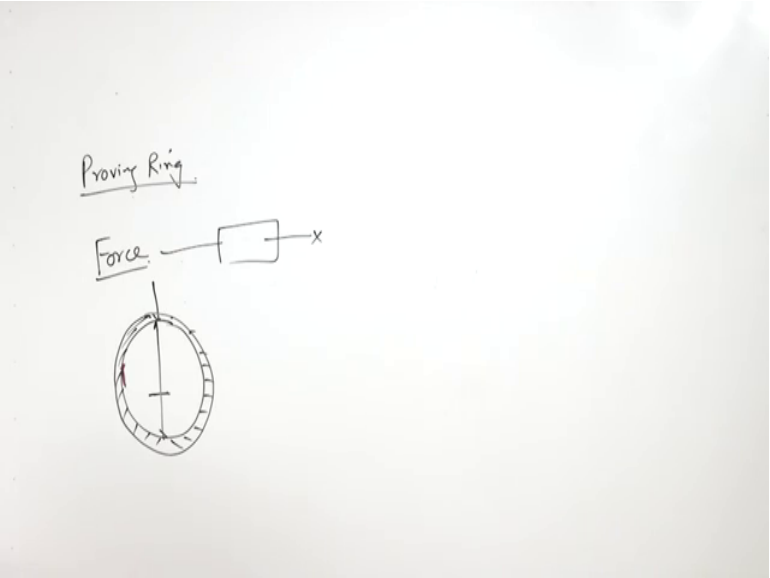

And, proving ring is nothing it is a ring, metallic ring and force is applied on this ring and we just say how much displacement how much change in diameter is taking place. So, in this metallic ring force is applied and we just measure how much change in diameter is taking place when we apply force and the when the force is applied on the ring it is in a certain thickness, right.

So, inside on the inside wall of this proving ring compressive strain is developed compressive it is under compressive the stress and outside is under tensile stress and both are same in quantity and both are same then the signal we get I mean amplified signal or better signal. So, this is a better option than the cantilever. So, proving rings are used and the output is displacement in importance force.

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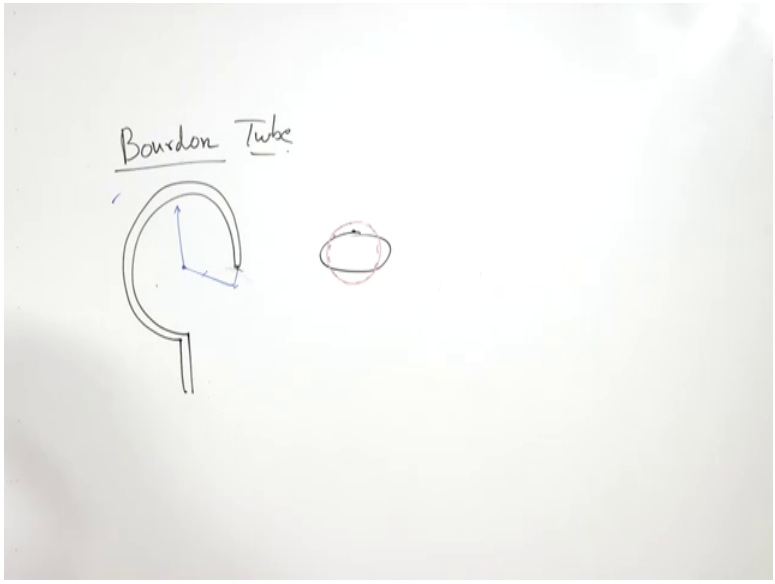

likewise there is another very interesting device that is bourdon tube it is used in the pressure gauges. Now, it was invented by a French scientist in 1849 and bourdon tube is a curve tube, right of 270 degree angle, but here the external force is not applied on the bourdon tube on the bourdon tube I will make hollow section, it is used in the pressure gauge.

So, when this tube is pressurized the cross section area of this tube is elliptical it is also a metallic tube, thin foil metallic tube the cross section area is elliptical. When this tube is pressurized right this elliptical section tends to become circular first of all this is the tendency of elliptical section to become circular and on the free end extension of this tube takes place on the free end extension of this tube takes place.

Now, we can have a relationship between the force in the in the tube and extension of the tube right fit the suitable mechanical system this extension this extension can be transmitted to the center of the tube and for ultimately to a middle or the to a pointer. So, this tube is specifically used for pressure measurement.

Similarly, because they are classical mechanical devices for measurement and as a mechanical engineer we should know a little about these devices that is why I am not going into the details of the analysis because nowadays we are using simply transducers, right, but these devices are also important and they have a number of applications only these devices are used, right.

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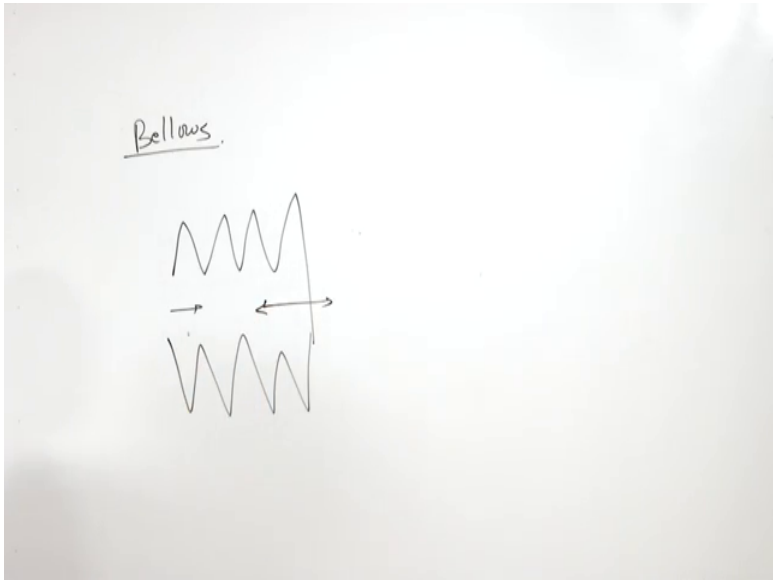

Now, second is bellows this is the third one bellows. Now, bellows are this is the one piece for the first of all there is a one piece and they can expand and contract in horizontal direction right like you must have seen in the back side of the harmonium. So, in the back side of the harmonium is also their bellows they are very flexible for the movement in x direction or the particular direction.

So, these bellows are also used the application can be seen as in the case of bourdon tube or any type of pressure any type of pressure when it is coming here right on the diaphragm of the bellow the bellow will move in this direction we can always relate force or the pressure as a function of displacement.

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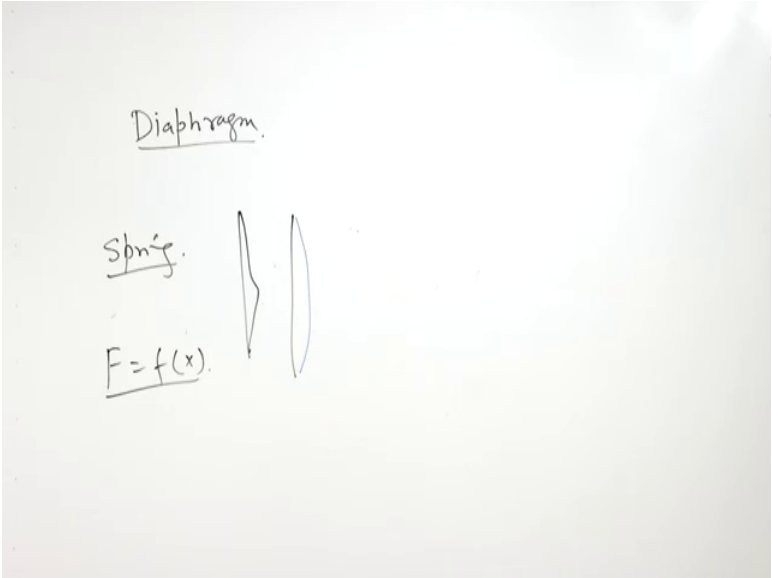

Now, after bellows there is one simple mechanical device which is used for measurement is diaphragm. Now, on the diaphragm suppose there is a flexible cloth let us take flexible cloth, right when I when I poke a pen on the on the cloth the cloth will immediately deform a projection will be formed here, right. If I put a pressure on the cloth suppose there is a diaphragm I will not take cloth it is a diaphragm. So, if we push a pressure on the diaphragm the diaphragm will bulge in this direction in a particular direction, right.

Now, in this case suppose I put a strain gauge strain gauges I will be telling you details later on, but here if I put a strain gauge what is going to happen with a strain gauge. So, a strain gauge will give the reading of strain developed here right and this strain I can always correlate with the pressure applied on the diaphragm, right. A spring can also be used as a as a mechanical sensor a spring as you I need not explained in details about the spring it is also always a function force is a function of x or f is equal to kx.

So, input is force and the output is displacement say spring is also a mechanical detector can be used as a mechanical detector.

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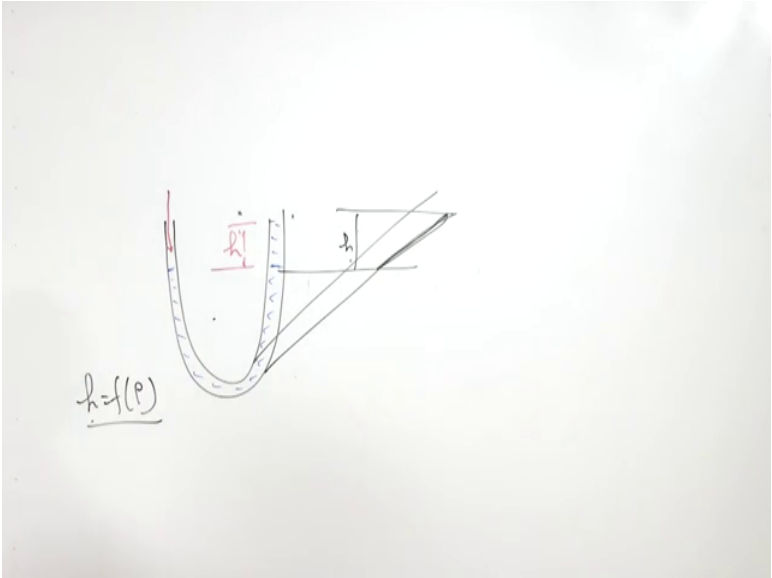

Manometer can also be used as a mechanical detector because if you it is a let us talk about very popular U tube type of manometer where fluid is filled certain fluid is filled and all these parameters and all will be discussing when I will discuss about the pressure measurement. I am just giving you an idea, this manometer is filled with some liquid and liquid will find this limit by itself.

Now, if we exert pressure from this side the pressure is exerted from this side definitely this side is atmospheric pressure the lift will be lifted and a h will be developed and h rho g will give the pressure difference, right. Now, in some of the cases this h is very small maybe 1 millimeter or 2 millimeter h is a function of density of the fluid which is being used, h is a function of density of the fluid which is being used. So, now, I want to amplify this function.

So, in order to amplify this function what I will do I will make this lag inclined. So, instead of making it vertical I will make it like this once I make it like this in that case this h will be amplified now we can read from here with the inclined scale and with the inclined scale definitely the signal with. So, this is how the output of the transducer can also be manipulated and the objective is better reading better measurement and measurement which is error free.

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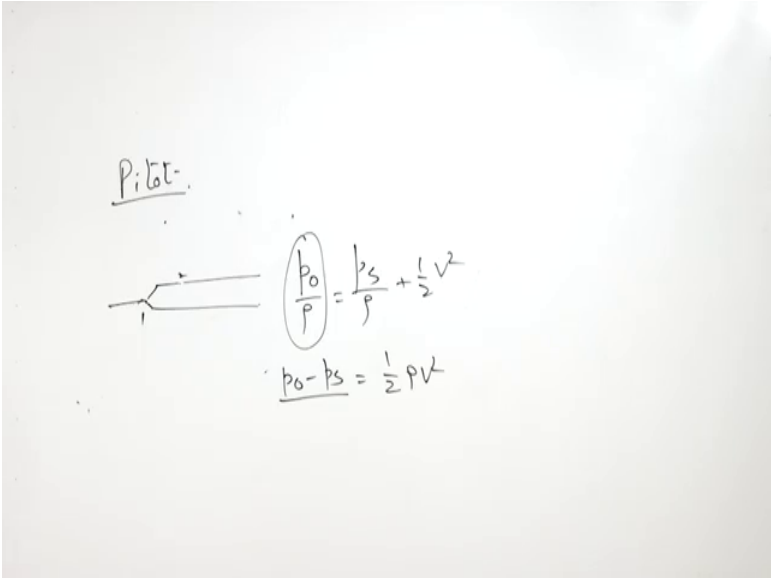

Now, after manometer there is a pitot tube. Pitot tube also will discuss in details in subsequent lectures pitot tube. Now, pitot tube is used for converting velocity into the pressure because in pitot tube there is if you remember there is a tip of the pitot tube and from pit tip suppose this is point one this is point two right and at point one there is a stagnation pressure at point two there is a static pressure and difference of a stagnation pressure because the stagnation pressure is half V square sorry stagnation pressure is a static pressure by rho plus half V square.

So, once we know the stagnation difference between stagnation pressure and the static pressure then half or rho V square. So, V can always be calculated because density of the fluid is do not verse, right. So, there are certain scope of error in the measurement of pitot tube as well that we will discuss later on, but this is a very excellent device and it is a passive transducer it does not require any energy. So, it is a passive transducer and very comfortably we can because in the in the initial systems also nowadays still nowadays a lot of places this pitot this is very reliable device for the velocity measurement because those measuring instrument which are not consuming any energy we are normally very reliable. So, pitot tube is also reliable method of doing measurement of velocity.

And, the last one is thermometer normal thermometer that is liquid in glass thermometer. So, liquid in glass thermometer also I have amply discussed liquid in glass thermometer. So, in liquid in glass thermometer also the temperature, the change in temperature is

converted into the change in the volume of the fluid which is in the bulb and change in the volume of the fluid is also again it is converted into the displacement in a vertical tube very it is a very thin or it is a very small diameter tube. So, the signal is enlarge. So, these are the typical mechanical detector for the measurement, but normally we go for the electrical transducers.

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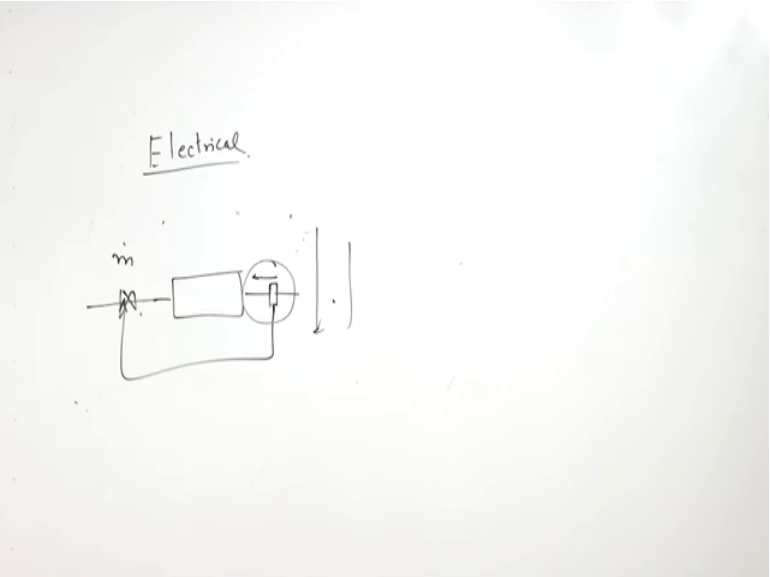

We go for electrical transducers the reason being there are certain reasons for this. The reason is amplification can be done easily because in electrical signals are easy to manipulate this simply put some power amplifier and you will get high magnitude signals, right. So, that is the benefit of electrical transducer mechanical transducers also we can magnify the signals, but there are certain limitations and in mechanical systems it is always I mean friction losses and backlash these type of scope of error is always there, right.

And, the mass inertia effect is minimum because the electrical system they they they have very we can maintain very low mass moment of inertia. However, in the mechanical case it is a little difficult. Friction is minimized I have already explained.

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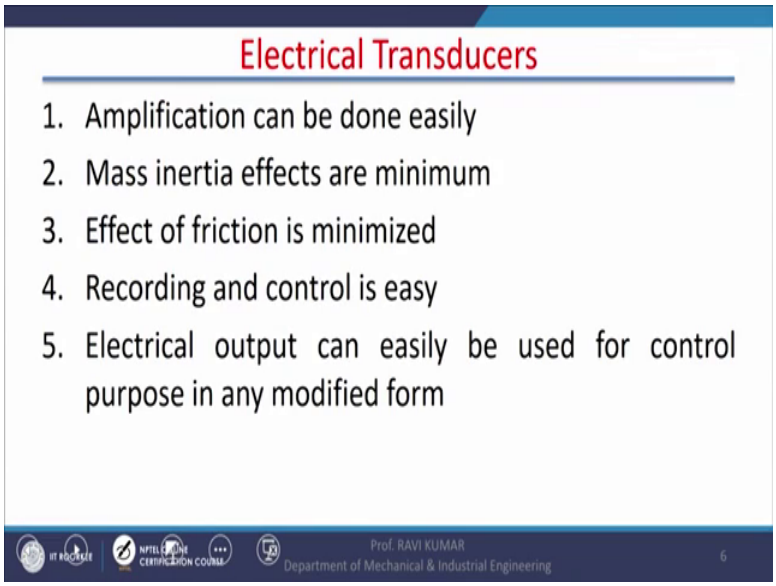

Recording is easy, I mean mechanical system Chardon pen type of recorder can be used I mean that can be one of the mechanical recording device, but nowadays nobody is going for the device because nowadays digital devices have come very advanced digital devices and data acquisition systems have come. So, all the signals whatever form they are available ultimately they are converted into the electrical signal, digitized and stored and these and other benefit of this electrical output is it can be very easily used for the system control as well.

Whatever coming what I am talking about the feedback control suppose there is an there is a system, right and output is coming from the system. So, there is a there is a wall suppose right and I want to maintain certain mass flow rate through this wall. Now, here with the help of a transducer I will measure the mass flow rate. If it is exceeding the certain limit immediately the feedback will go to the wall it is actuated wall and the wall will close, the mass flow rate will reduce and it is when the mass flow rate is going below the prescribed limit then this wall will open the mass flow rate will increase. So, these type of manipulations are easy.

Even in mechanical systems also I mean for example, governing of hydro turbine and also mechanical feedback control systems are also there, but the applications is very are very limited and for electrical signals manipulation in easy and feedback control is also easy when we have mechanical signals with this.

Now, classification of transducers active and passive transducers I have already explained you. Primary and secondary transducer; primaries transducers and secondary transducer mean if there is a transducer which come into contact with the measurement that is a primary transducer and sometimes the transducers are not in contact with the measurement after one transducer there is a there is sensor and after sensor I mean the sensor is built inbuilt in a transducer then signals are going to the another transducer.

So, those type of arrangements are known as are given in the second type of and this type of arrangement is known as second type of secondary type of arrangement of transducers digital and analog I have already explain you, but we should not confuse that we should not get confused with the fact that digital output of the system is error free. In fact, the most of the system which have very high accuracy have analog output.

So, even for the calibration for the calibration purpose or the primary systems which are used for the calibration purpose, right, so, in those systems which are used for the calibration systems the analog or type of output is there. So, analog type of output and digital type of output has got nothing to do with the error in measurement.

But, definitely if you want very highly accuracy one should go for the analog type of system and transducers also there can be analog type of transducer there can be a digital type of transducer. For example, the thermocouple it is an analog type of transducer because signal is a mini volts and we just simply put the voltmeter across the terminals and we get the output from the transducer.

Input and output of the transducer input type of transducer is some phenomena is given is a input of the transducer output in a electrical signal and when you reverse it, I mean the some electrical signals are going to the transducer and on the other side some phenomena is taking place that is known as output transducer.

This is all for today. From the next class we will go for the selection of the transducers and the classification of the transducers.

Thank you very much.