Mechanical Measurement Systems
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Lecture – 06
Static Characteristic of Measuring Instruments- 2

Hello, I welcome you all in this course on Mechanical Measurement Systems, and today we will continue our discussions on static characteristics of measuring instruments. So, topic to be covered is today only the static characteristics of measuring instrument because it was left incomplete previous time.

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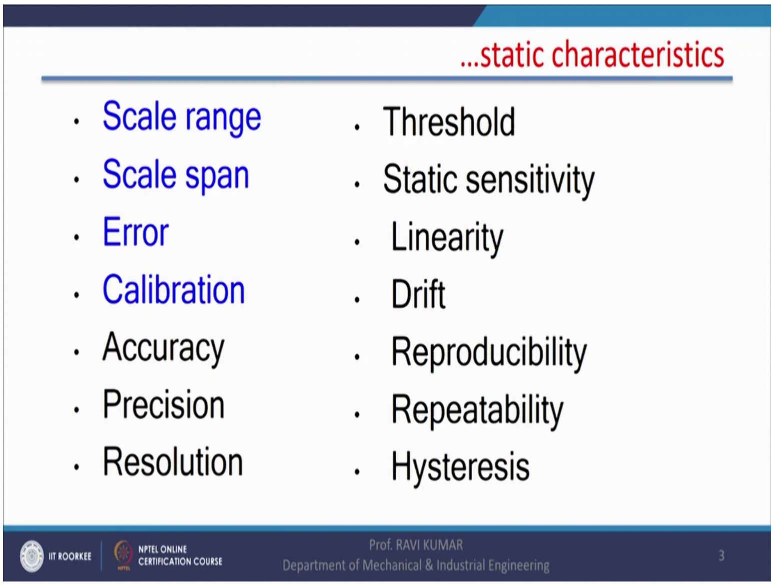

We have already covered the scale range, scale span error and calibration. Now, we will start with accuracy and precision there are two things which is accuracy and another is precision.

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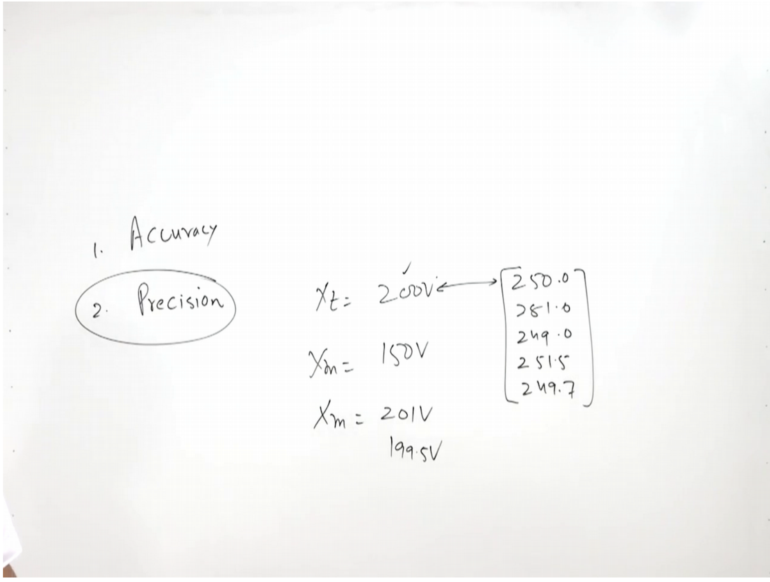

Now, accuracy means high how close the measurement is to the true value. So, accuracy in fact, is a manifestation of error in measurement if the error in measurement is high then the accuracy of the instrument is poor. For example, if the input is 200 volts right and instrument is giving a 150 volts, the reading is X m is 150 volts, the true value is 200 volts we will say that accuracy of the instrument is very poor because order of error is very high. Instead of that if the measurement measured value is 200 and 1 volts or 199.5 volts then error is very small right.

And then in that case we can say that accuracy of the instrument is very good. So, accuracy is direct manifestation of error in measurement. Now, the accuracy should not be confused with precision, precision is entirely different thing precision in, precision means agreement between different readings it has got nothing to do with the error true value is 200 volts right. Instrument is measuring 250, 251, 249, 251.5, 249.7 right very precise subsequent readings are very close to each other.

So, precision is very good, but if you look at the accuracy, accuracy is very poor. So, if I say the instrument is very precise the precision is high it does not mean that the accuracy of measurement is very good. The precision simply means the agreement between subsequent readings if you take n number of reading highly high highest order of precision is you get all 250.0, precision is 100 percent, but accuracy at the same time accuracy is very poor. A very popular example is given for comparing the accuracy with precision is shooting targets.

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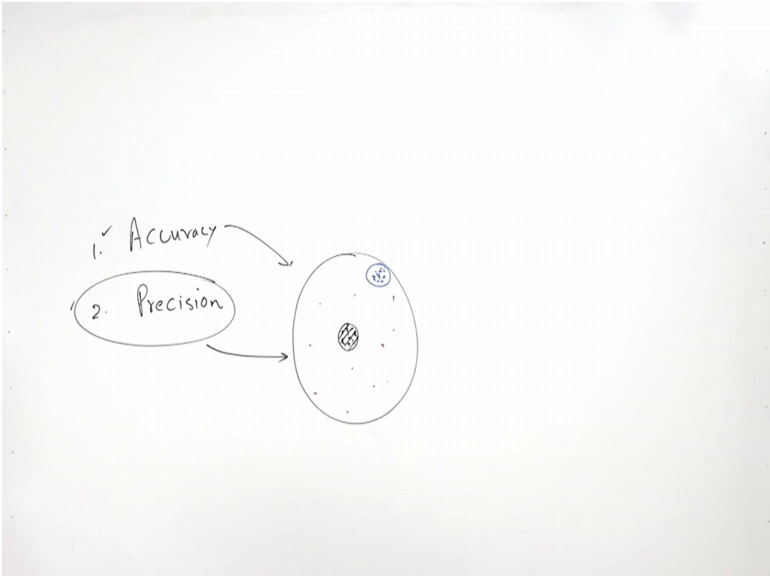

Suppose in a shooting range rhis is a shooting range and you must have seen in the shooting range there are different circles and there are different points for different circles and innermost dark circle is known as bulls eye. An objective of every shooter is to hit at the bulls eye. Suppose shooting or the shooter has very high accuracy right and then in that case and very high precision also, very good shooter is a dead shot in that case all the bullet us will be in this region right accuracy is good because he is getting ten points for all the shots at the same time there is mutual agreement between different shots they are very close to each other. So, accuracy is very good and precision is very good.

Now, I come to the next case where accuracy is poor and precision is excellent. Suppose all the shots are here, in that case he is getting very less point he will be getting minimum point for this short maybe one point to two point. So, accuracy is poor because it is far away from the target accuracy of shooter is poor, but precision is very good all the bullet us are coming at the same point or very close to each other right.

So, this is the case when accuracy is poor, but the precision is high and of course, if both are poor accuracy is also poor precision is also poor then the target will have scattered bullets, any bullet going anywhere. So, it I mean accuracy is also poor in this case and there is no precedence no agreement between different shots. So, this is another way of comparing accuracy and precision. But in good instrument should have both excellent accuracy and excellent precision as well right.

Now, after these two because we will take the resolution, now resolution is suppose we give input to the instrument and we get certain output. So, the minimum output is sorry minimum input for which the instrument is sensitive that is known as resolution right. Resolution of the instrument can be the least count of the instrument as well right, but the if you if we want to go by the definition the definition is minimum amount of input for the is for which the instrument is sensitive or instrument can detect that is known as a resolution.

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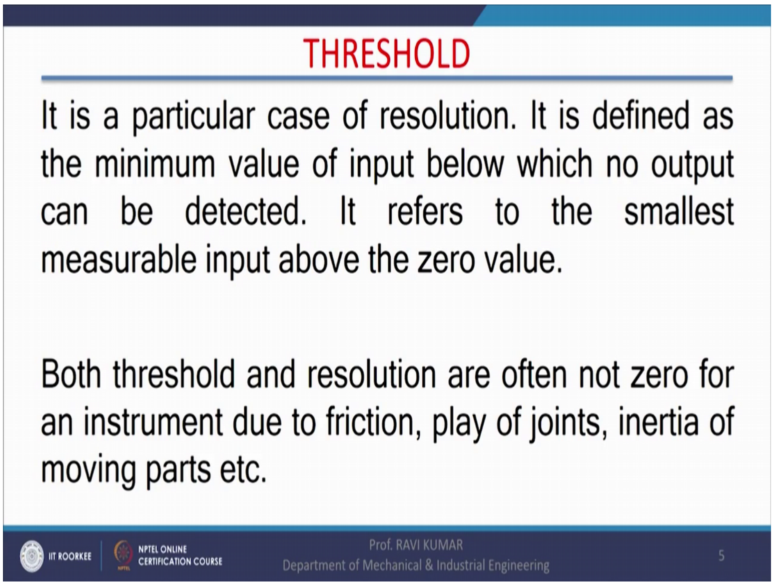

And second thing is threshold, the two terms like accuracy and precision that the another two terms which are normally confused they are resolution, number 1, resolution and number 2, threshold right.

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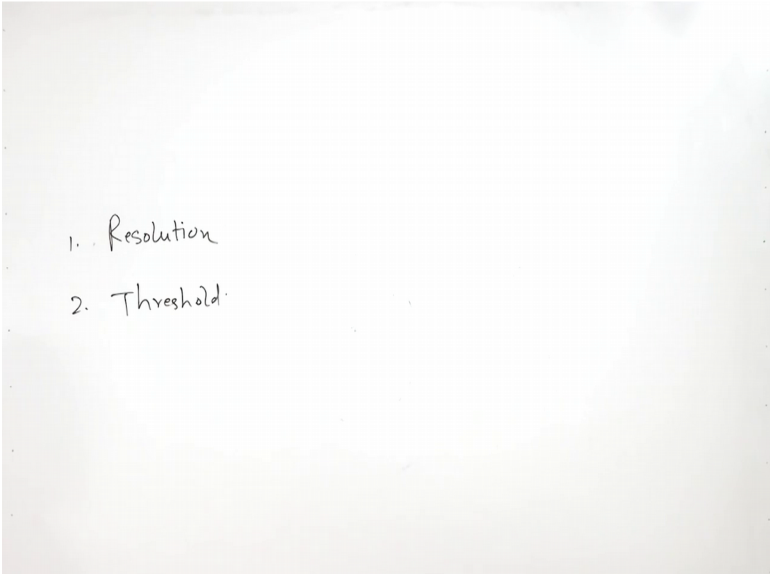

So, resolution is the minimum input to which the instrument is sensitive or change in the input not input change in the input, minimum change in the input to which the instrument is sensitive ok. Threshold means when we start from 0 minimum input required to have to have output from the system from output of the instrument. So, that is known as threshold right. So, this is the basic difference between resolution and, so they are never zero. Actually an ideal instrument should have zero threshold value and the zero resolution also I mean it should be very sensitive infinitely say it should be sensitive to the infinite decimal input the instrument. But normally it does not happen.

Certain amount of change in input is required to have any change in the output from the instrument threshold ideally it has to be zero, but in actually what happens due to inertia of the instrument or due to many other reason may be the friction may be the inertia of the instrument. The minimum, a minimum amount of input is required to have output from the instrument. So, this is the, this is how we can we can differentiate between a resolution and the threshold.

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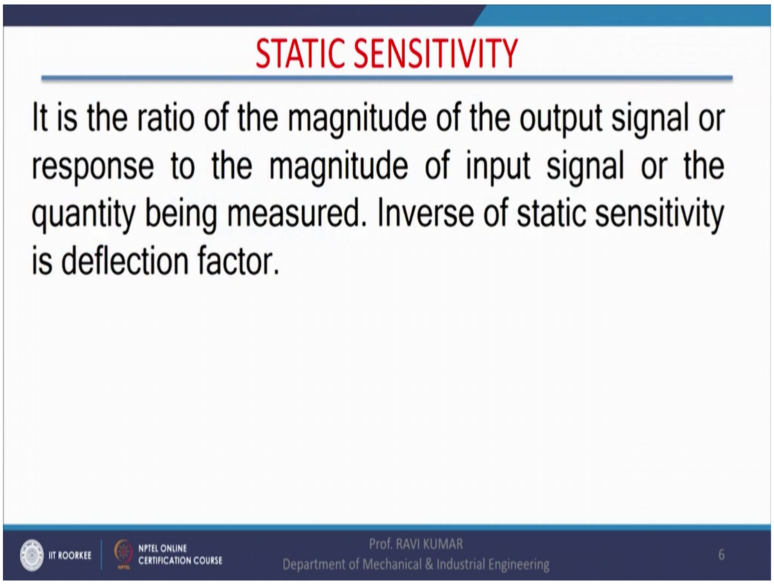

Now, static sensitivity that is very important and frequently we will be discussing this a static sensitivity of the instrument. Static sensitivity is the static characteristics of the instrument. So, static, static sensitivity of the instrument.

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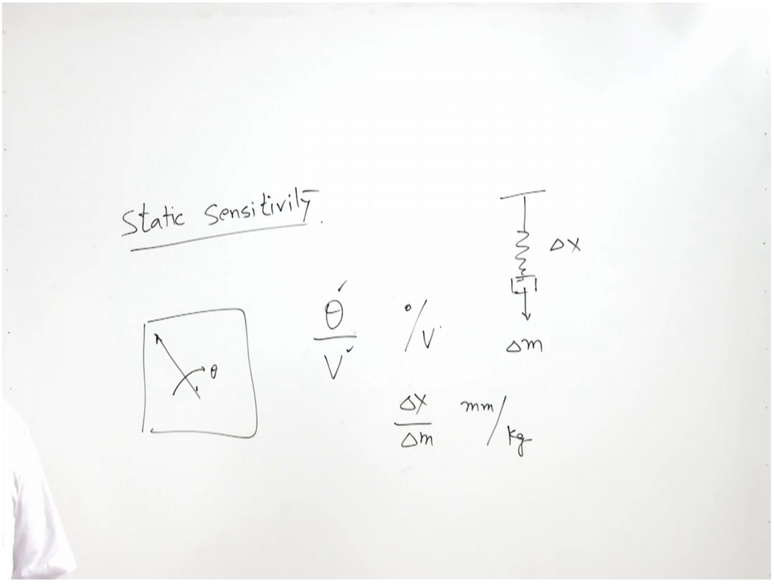

It is the ratio, static sensitivity is the ratio of the magnitude of output signal or response to the magnitude of input signal that is it. Suppose input signal is for example, let us take example of volt meter because it is simplest example to explain the things, in the voltmeter there is a indicator right and indicator moves at a certain angle theta when voltage is given. If the voltage is low theta is low and voltage is high the value of theta is high. So, static sensitivity of the instrument will be theta by V change in the angle divided by the change in the voltage. So, change in the input. So, change in the output divided by change in the input or it can be expressed in terms of degree per volts, this much degree per volts.

Another example of a static sensitivity can be given suppose you are using spring as a in a wing machine or for the purpose of wing right, for a particular change in the mass there is a certain displacement that is output of the instrument displacement right. So, static sensitivity of the instrument is going to be displacement divided by change in mass or mm or meter or centimeter per kg, that is static sensitivity of the instrument it means magnitude of output or change in the magnitude of output divided by change in the magnitude of input.

Now, static sensitivity is a characteristic of a static characteristic of the instrument, but while analyzing the dynamic characteristics of the instrument this is also taken into account, when this we will discuss when we will take the dynamic characteristics of the instrument for the discussions. Right now we are discussed the a static characteristics and this is the one of the important characteristic of instrument. It also shows the sensitivity of the instrument, how the instrument is sensitive to the input right, but by the definition it is change in output signal divided by change in input signal.

Now, after static sensitivity there is a term linearity.

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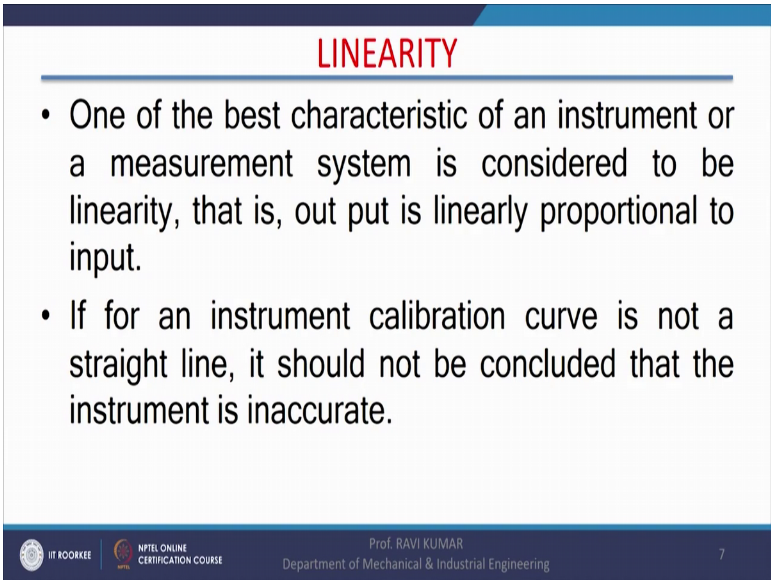

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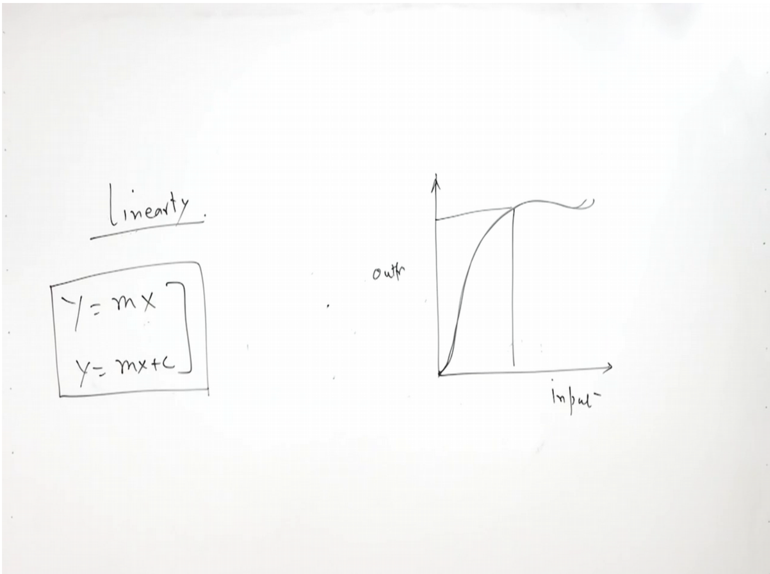

Ideally an instrument has to be linear. The response of the instrument has to be that is the ideal case, Y is equal to mx or Y is equal to mx plus c. Instrument should follow the linear. I mean if you draw the curve between input and output it should be a straight line, that is the best proportion and that is always desired right. But it normally does not happen.

The students sorry the instruments many of the instrument or most of the instrument do not have linear response. Instrument can be non-linear also, response of the instrument the characteristic curve instead of having a straight line the characteristic curve can be like this right, but it does not mean the instrument is inaccurate. It has got linearity has got nothing to do with the inaccuracy in the measurement because once we have a calibration curve we can always have the true value of the instrument right, but we should have this curve with us.

Normally, what happens? Nowadays electronics has developed. So, non-linear response of the instrument is often converted into the linear response by using some electronic circuits, right. So, this is the best way of having the input output relationship. So, in an experiment suppose the instrument is having certain response instrument is having certain response, this is input and that is output and there is a ideal case right. But we are having the response of the instrument is like this we are having your data points right, this is the measured value which is shown by the dart curve sorry the red curve.

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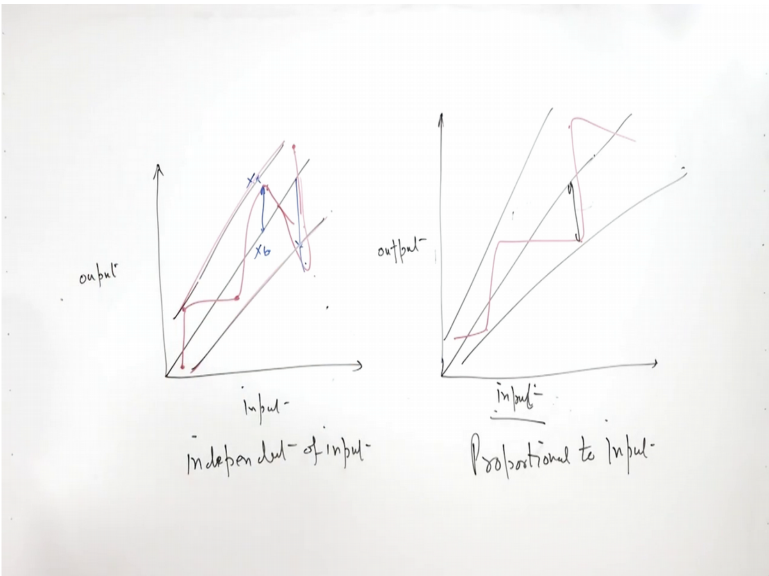

So, non-linearity in the measurement can be expressed by this, this is a non-linearity in, this is a non-linearity X a difference between X a and X b right, this is known as non-linear. There is a maximum deviation maximum deviation can be here, but visually I can find the maximum or suppose this is the maximum deviation then this is going to be the non-linearity, non-linearity in the characteristic of the instrument.

Now, this can be independent of input constant, this can be independent of input right or sometimes what happens input output characteristics change, in that case you are going to have this type of response like this, the input output characteristics is changing. So, it is going like this and if you draw the line it is going to be like this. Now, here the slope is same, but here the slope is changing and non-linearity will be again the maximum deviation may be like this, maybe this one that is known as non-linear non-linearity in the measurement non-linearity in the response of the system this is the output and this is input right.

And the third kind is combination of these two. So, partly the instrument is responsive proportional to the input right sorry, independent of input and partly it is proportional to input. So, this is the case when the response is independent of input of input, and this is the case when it is proportional to input right. And we can have a combination of these two not strictly the instrument phylo either this or this, it can have combination of these two. So, it is it means that it is independent of input for a certain range like this and then it becomes proportional to input as well.

Now, there is a very important term in a static characteristics is drift.

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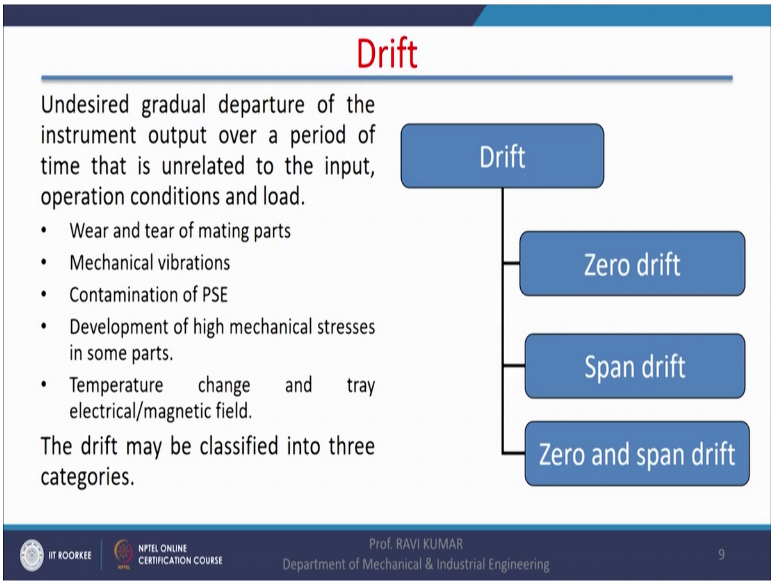

Drift is undesired departure from sorry drift is, so drift is undesired departure of the instrument output over a period of time.

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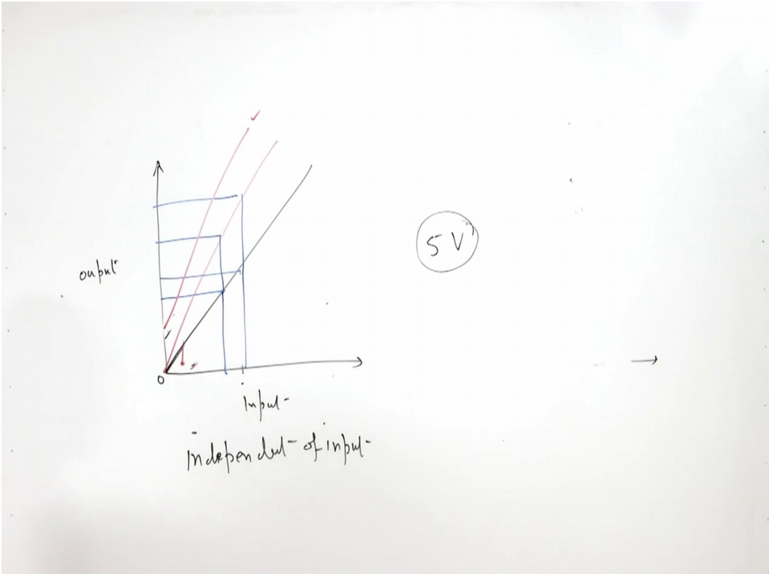

It means that this is actual characteristic curve linear characteristic curve of the instrument and over the period of time over the period of time. Suppose there is a mechanical measuring instrument wear and tear of parts may take place right and that may cause some backlash or some play in the instrument or for some other reason instead of this the zero is shifted, input output relationship is same this is known as zero drift, zero drift.

So, initial reading is not zero initial reading may be say for example, if you using a voltmeter using a voltmeter. So, for zero input initial reading is five volt, but input output relationship is not changed only there is a shift in zero do due to prolong use of the instrument some error permanent has error has scraped in and you must have realized this also in actual practice and then rest of the input you are getting the reading. And just you, simply make corrections from these five volts and you will be getting the true value true characteristics of the instrument. So, this is known as zero drift another is a spanned drift.

Now, what happens in the spanned drift? In spanned drift the input output characteristics is change right initially it may be at 0, but the characteristics curve is shifted to a new position or the slope has change. So, when the slope has change in that case input output relationship has changed. So, for a given change in input right, for a given change in input this was the output. Now, for the give same giving change in input we are going to have this change in output. So, this is known as span drift and again there is a combination of both 0 and a span. So, we can have instead of this we can have this type of drift also.

So, this is a combination of zero drift and a span drift right and this takes place due to, I told you earlier wear and tear of the meeting parts some mechanical vibrations are there in the instrument sometimes primary sensing element is contaminated. Now, primary sensing element of the instrument is that part of the instrument which comes into the contact of measurement. For example, thermometer or you are using thermocouple for the purpose of measurement and while making the bead of the thermocouples and contamination has taken place right, in that case the error will again come into the your measurement and this type of error or this type of deviation from the actual reading is it comes under the drift of the instrument because it is permanently there.

Once the tip is contaminated it will be permanently there. So, it may change the it will definitely in case of thermocouples it will definitely change the input output relationship. So, it is going to be a span drift. Sometimes, development of high mechanical stresses in the system suppose you are using a spring right. So, high stresses also if you stretch spring beyond a certain limit then also input output relationship will change for example, there is a change in temperature with temperature also input output relationship will change with presence of magnetic field also the electromagnetic field also the input output relationship will change all these results in the drift of the instrument.

So, after the drift will take repeatability and reproducibility.

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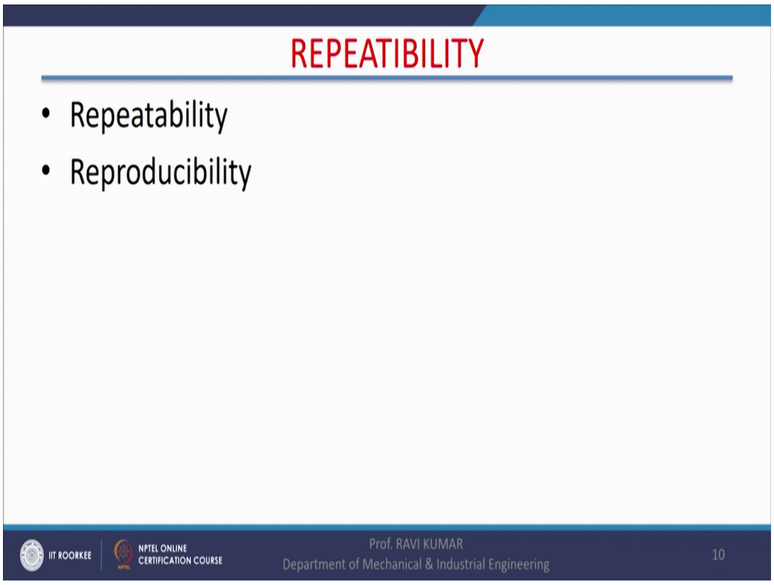

There are two things repeatability and another is reproducibility, repeatability and reproducibility.

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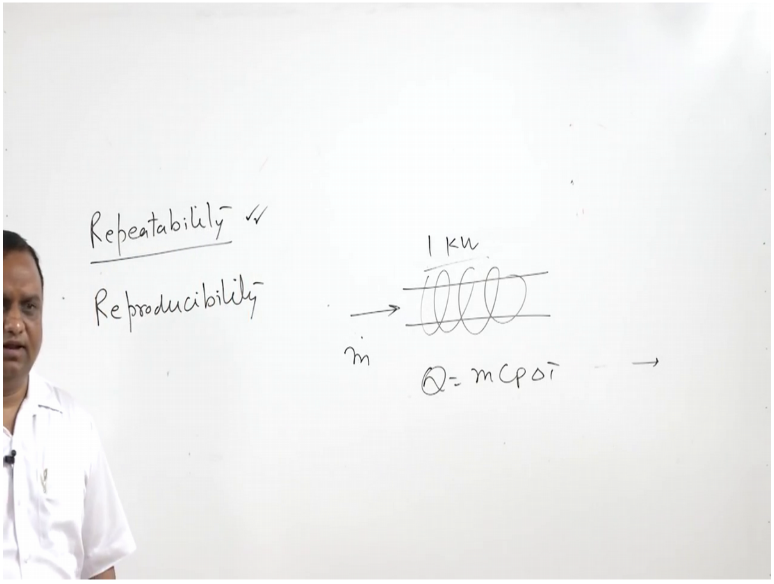

Repeatability means if you take n number of observations, suppose I am measuring the temperature of this podium with the thermometer at the same time I take 100 of observations all the observation agree with each other then repeatability is hundred percent excellent or repeatability is directly connected with the accuracy of measurement sorry the precision of measurement right.

So, if I take 100 times of reading repeatability is good, 100 percent or if all the observations are agreeing with each with each other. Second thing is if I am conducting an experiment I am conducting an experiment, suppose I want to have suppose there is a pipe surrounded by the heating coil, water is flowing in a pipe I conduct one experiment right. Heating coil is giving 1000, sorry 1000 watts or 1 kilowatt sorry I will write 1 kilowatt, 1 kilowatt, 1 kilowatt heater then water is flowing with a certain velocity mass flow rate right and then we calculate Q is equal to mcp delta t something like that we are conducting on an experiment. And again and again we conduct the experiment and we are getting and we have to find the value of delta t here and at the same time we are getting the same value of delta t. So, repeatability is good right.

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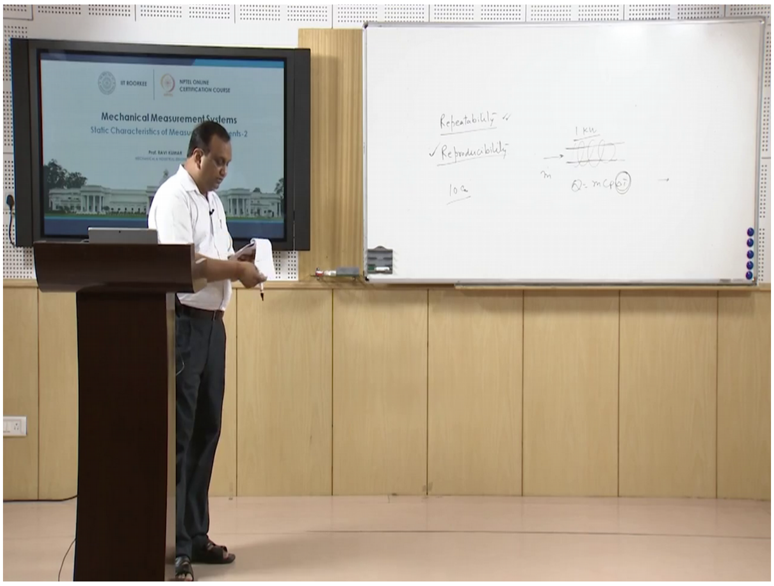

Now, case comes the reproducibility, reproducibility means some other place, some other place some other frame of time I fabricate another setup right. And then again I use another coil I mean and if use a I mean different pipe I mean it is all together suppose the experiment is conducted what experiment I conduct here somebody else conduct experiment in some other place having the same dimensions, but they take different pipe different heating coil, different sample of water or available water. In that case are they getting for 1 kilowatt heating the same temperature difference that is known as reproducibility right.

So, there is a distinct difference between repeatability and reproducibility. Reproducibility means you are using a different sensors, different setup suppose I make a ring here in my factory and the ring diameter is 10 centimeter and with the help of a caliper or some measuring instrument I measure the diameter of the ring. I do it 100 times or 200 times and that will reflect the repeatability of the measurement. Reproducibility means the ring is produced in some other factory of same material and same dimension and with the same different instrument it is measured again and again and that is known as reproducibility of the data right. So, there is the there is a distinct difference between repeatability and reproducibility.

Now, the next one is hysteresis.

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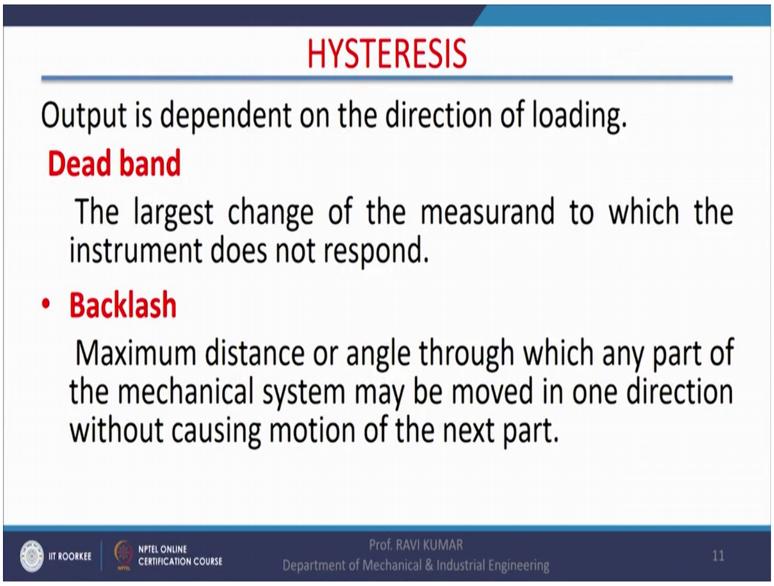

In electrical equipment also we have hysteresis. In mechanical equipment also there is a concept of hysteresis.

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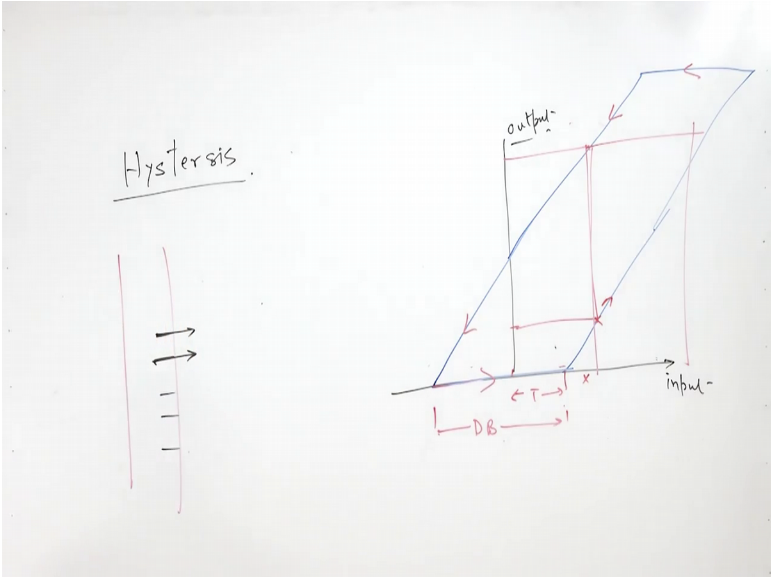

Now, hysteresis by definition hysteresis means, hysteresis means the output depends upon the direction of loading, in electrical instruments also you must have seen the hysteresis curve. In mechanical instruments also or measuring instruments also there is a hysteresis and here the hysteresis is a little of a little different type right we have normally hysteresis curves like this is input this is input and this is output.

Now, hysteresis means the output of the instrument will depend upon the direction of loading. For example, if we take a flow meter right and if we are increasing the flow rate suppose there is a they are divisions of the flow meter, when we are increasing the flow rate right when we are increasing the flow rate then we may the that we for a particular flow rate we may get reading here right. But when we are reducing the flow rate for a particular flow rate we may get reading here. So, direction of loading is important here.

So, here also I will just improve this curve it is doing a lot of too much of hysteresis, is to like this. Now, here this is the direction of loading, for a particular input suppose the input is this one right. When the input is increasing the output is this much. Now, after this the loading is reversed and we are coming back to the original position. So, this is the output, but while returning you may find this for this is the output for this, for the same input.

So, we are having two outputs for the same input. So, output is depending upon the direction of loading in which direction the instrument is loaded where the load is increasing or load is decreasing. Now, here as I stated earlier threshold, if we look at the threshold this is the 0, this is threshold, minimum amount of input which is required for having some output. So, this is known as threshold and this part is dead band because from here to here there is no output, this may be due to I mean slip in the matching parts right, slip in the matching parts or may be due to tolerance also. But this is happening and this entire range is known as dead band or there may be a backlash in the instrument also. So, backlash due to backlash also there is a change in the input, but there is no output right.

And then we have because this is the direction of loading ok. So, this curve is known as hysteresis curve right or in the same curve we can have for the same output we can have two inputs, either way it can be explained right. So, we have covered the dead band backlash.

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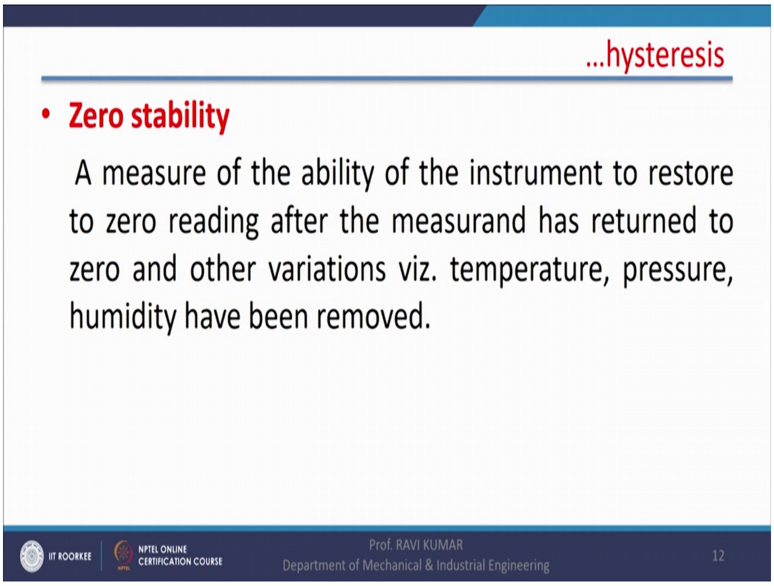

Zero stability, zero stability means whatever input you give to the instrument and when the input is removed input signals are removed the zero is stored in the in the instrument, zero is displayed in the instrument. This is known as zero is stability of the instrument and this is very important and how quickly the instrument restores the zero stability that reflects the quality of the instrument. So, that is all for a today.

Thank you.