Mechanical Measurement Systems
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Lecture – 05
Static Characteristics of Measuring Instruments- 1

Hello, I welcome you all in this course on mechanical measurement systems and today we will discuss about, the static characteristics of measuring instruments. In today's lecture we will discuss first of all the performance characteristics of instruments then, static state characteristics of instruments and error in measurement.

Now, if we choose any instrument, if you want to purchase any instrument the performance criteria of the instrument takes the major importance. Because, when we are purchasing any instrument we must know what is the performance of the instrument? And in order to compare the performance of different instruments there must be some criteria and definitely we like to go for a best available instrument in the market for example, if you want to purchase a car.

So, the first and the for most question come into your mind that, what is the average of the car right? Now, the average of the car is not same for all the speeds, right? If you vary the speed, if you vary the load condition the average of the car will change. So, not only you are concerned about the on-design condition, that is ideal road condition and optimum speed what is the average of the car? But, you are also concerned about the off-design condition performance of the car as well if you know about the automobiles.

So, performance criteria and decision of the performance criteria is important. Now, we have to quantify the performance criteria because, once we choose a performance criteria we need figures for example, average of a car average of a car is let us say, 15 kilo meters per litre of petrol, right? So, we have quantified we have qualified that, the average of the car 14, 15 kilo meters per litre there we have some figure is 15 kilo meters. So, likewise we should have different basis for comparing the performance of the instrument for example, if I want to purchase a voltmeter if I want to purchase a voltmeter then, I will ask what is the accuracy of the voltmeter? Right? What is the least count of the voltmeter right?

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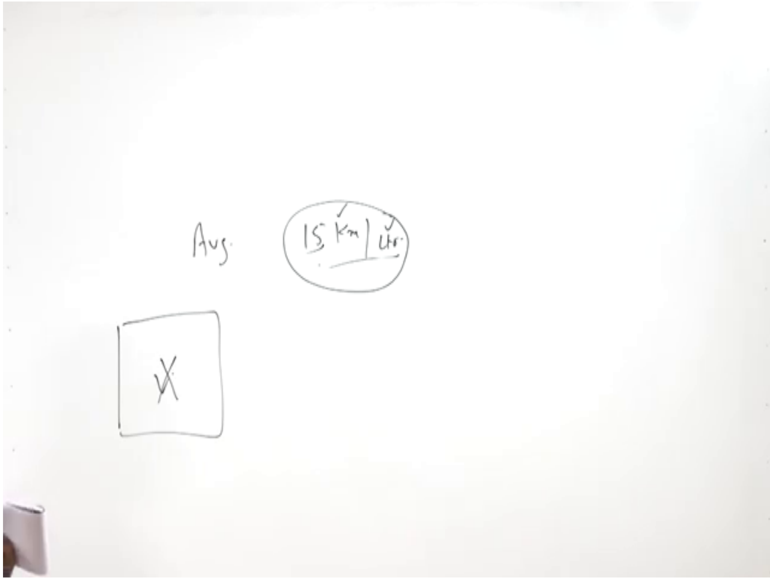

So, next thing is in addition to this your instrument, which you are purchasing should be sensitive to the desired input only it should not be sensitive to the spurious input then, it will give a faulty reading for example, if we purchase a voltmeter, voltmeter should not be sensitive to electromagnetic field surrounding the instrument because, if it is sensitive to the electromagnetic field we may get wrong reading of the voltage. So, first of all the quantitative basis of comparing the performance of the instruments now, the second thing is the instrument has to be responsive only for desired input not for interfering or spurious input.

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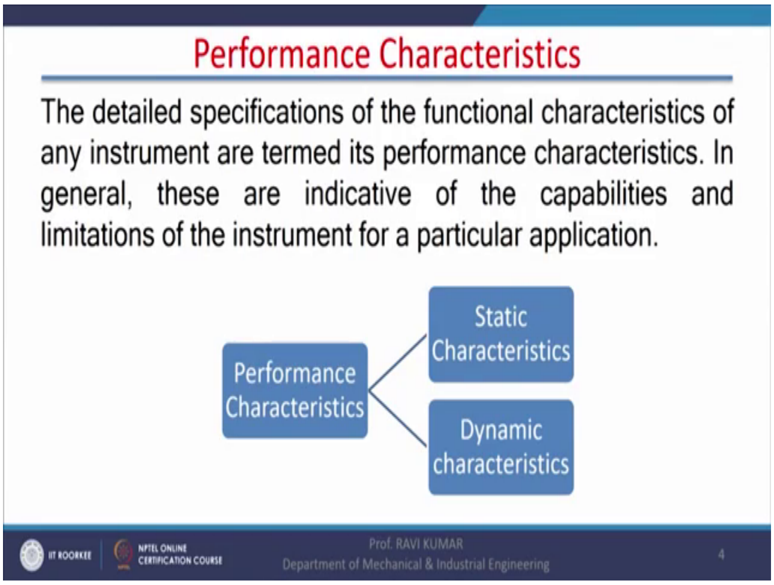

Now, after this we will start with performance characteristics of instrument. It is a functional characteristics of an instrument performance characteristics of functional characteristic of an instrument, it is indicative of the (Refer Time: 3:49) of the instrument for a particular application. So, performance characteristics of an instrument is indicative of capability of the instrument including limitations for a particular application and performance characteristics is broadly classified into static characteristic characteristics and dynamic characteristics.

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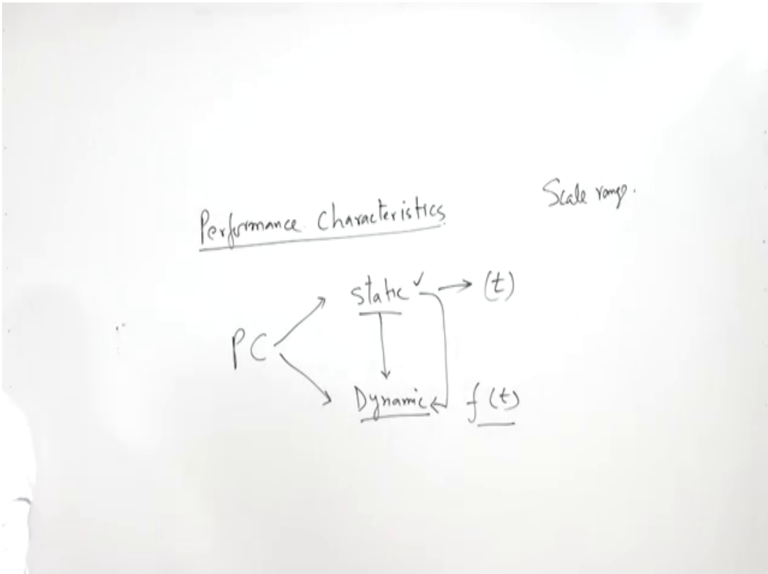

Now, what is static characteristics? Now, static characteristics means the characteristics of the instrument, which is independent of time or with time there is no or insignificant variation in the characteristics of the instrument for example, we are using a weighing machine. So, when the weighing machine is stabilized then, you leaving machine for 10 minutes, 20 minutes or 30 minutes it is performance will the weighing of the object will not change, right? So, that is static characteristic of the machine, but the weighing machine will take some times to be stabilize. So, that reflects the dynamic characteristics of the weighing machine, right?

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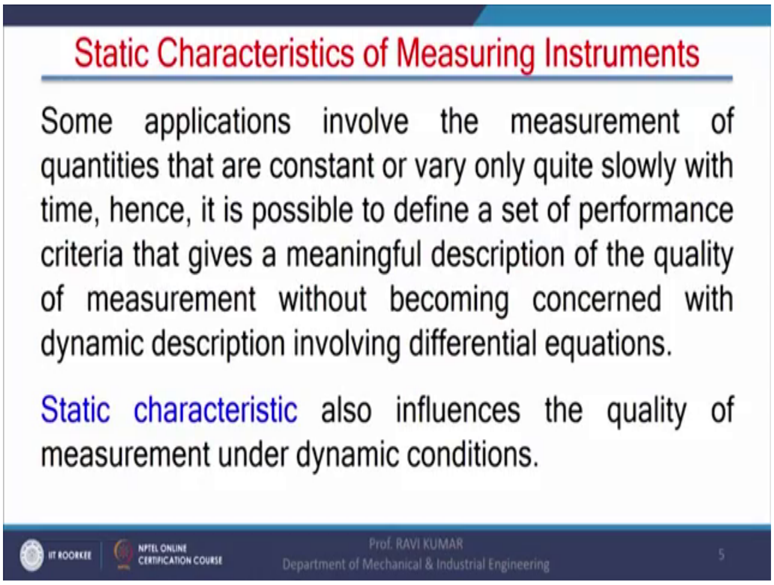

So, in static characteristics of the instrument; so, this static characteristic of instrument is also taken into account, when we analyse the dynamic characteristics of the instrument. So, while static characteristics we consume the characteristics, which is independent it is which is independent of time, but dynamic characteristics they are function of time and while doing the analysis of dynamic characteristics of the instrument the static characteristics also plays a very important part, right?

Now, there are certain static characteristics of the instruments will start with scale range, scale span then the error, calibration, accuracy, precision, this is resolution, than threshold, static sensitivity, linearity, drift, reproducibility, repeatability and hysteresis because, in electrical instruments there is hysteresis in mechanical instruments also there is hysteresis.

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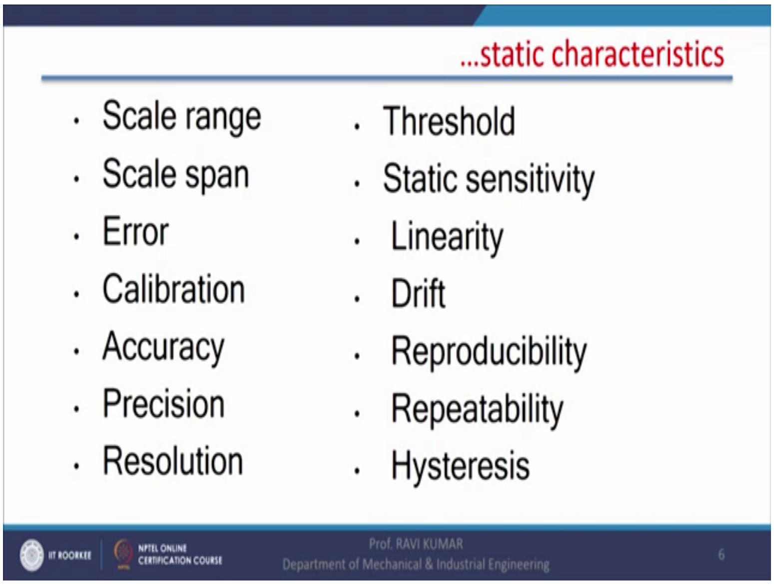

Now, first of all we will start with the scale range. If I say, a voltmeter can measure the voltage in a range of 0 to 100 or not 100 let us say, 200 volts a voltmeter can measure the voltage in a range of 0 to 200 volts.

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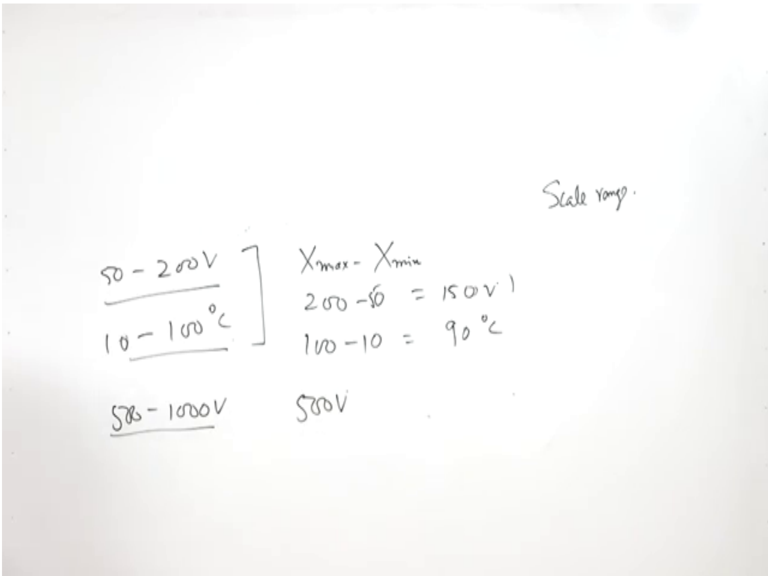

So, that is it is scale range or it thermometer, which can measure the temperature in a range of 0 to 100 degree centigrade that is scale range, right? Now, the second term is scale span now, a scale span is maximum value minus minimum value. Here, in this case the maximum value is 200 volts minimum value is 0. So, a span is 200 in this case similarly, it is 100 minus 0 it is 100 degree centigrade.

Suppose, this range is not 0 to 200, it is 50 to 200volts. So, a scale range is 50 to 200volts and span will be modified as 150 volts, right? Similarly here, if it is not 0 to 100 degree centigrade it is 10 to 100 degree centigrade in this case the span will be 90 degree centigrade I will give you another example suppose, if the voltmeter measuring between 500 to 1000 volts then, scale range is 1000 to 500and the span is 500 volts. Because, we will be frequently using this terms scale range and scale span.

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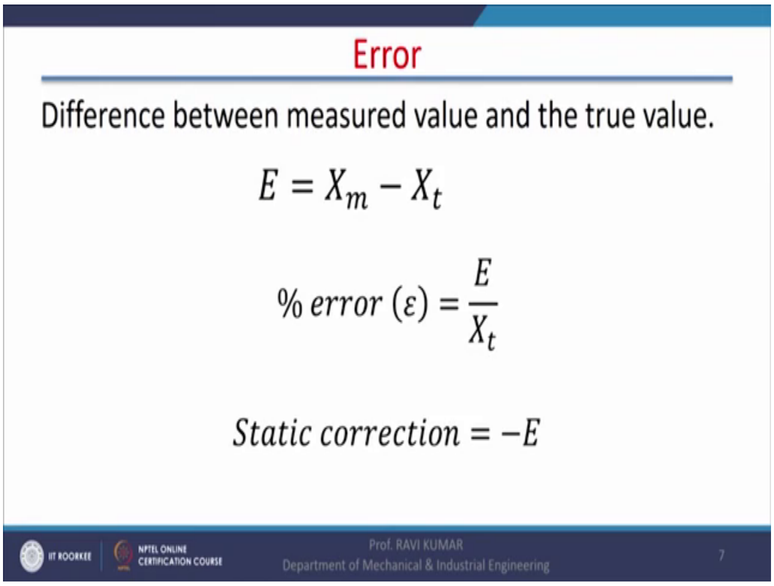

Now, the second characteristic static characteristics is error, error in measurement. Now, error in measurement is measured value minus true value, there is always difference between measured value and true value and error can be positive and error can be negatives as well, error also is expressed in terms of percentage error. So, percentage error is error in the measurement divided by true value. So, multiplied by of course, multiplied by 100. So, that is percentage error, right? And when we do the measurement we already know suppose instrument is calibrated then, we already know, what is the order of error in the instrument? Suppose and the true value is always measured value minus plus minus error in the measurement.

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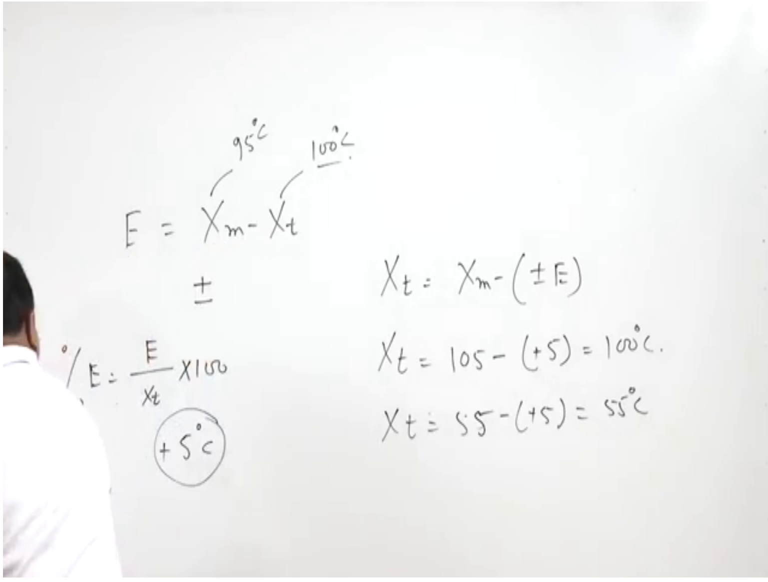

I will give you an example, suppose a thermometer has error of negative error of 5 degree centigrade, negative error means if the temperature is 100 degree centigrade it will read 95 degree centigrade, if temperature is 50 degree centigrade thermometer will reflect 45 degree centigrade temperature.

So, it has error of 5 degree centigrade because, measured value is 95 degree centigrade and suppose, true value is 100 degree centigrade. So, the error is minus 5 degree centigrade. So, if I want to have true value of temperature than, measured value is 95 minus 5 and that is going to be 100 degree centigrade, right? Suppose it is reading 50 degree centigrade. So, then true value is 50 minus 5 is equal to 50 degree centigrade.

Instead of that, if it is has positive error then, definitely here instead of getting 100 degree centigrade we will be getting if it is indicating 105 it has positive error instead of this we are getting 105. So, minus plus 5 minus and this is 50 minus plus 5 so, in that case also minus plus sorry, this will be giving 55 sorry, if it has now, I will repeat if it has positive error of 5 degree centigrade now, instead of 100 degree centigrade the indicated temperature will be 105.

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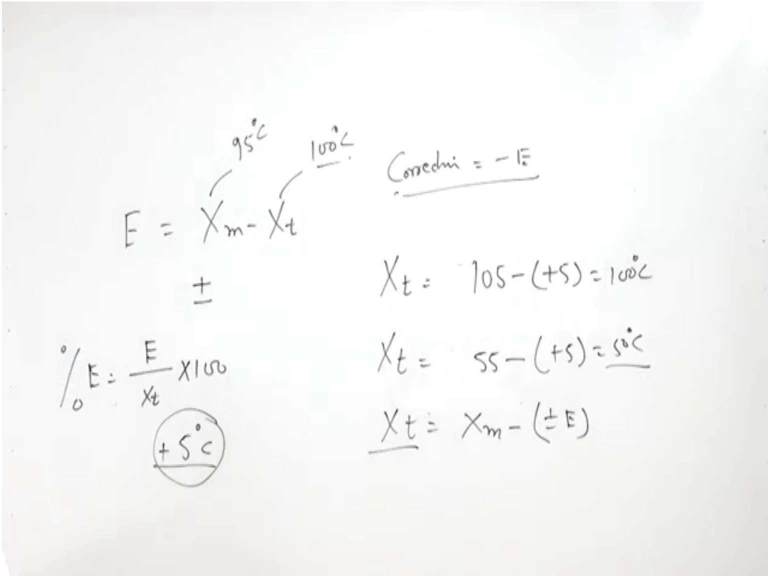

So, 105 minus plus 5 is 100 degree centigrade, right? And for example, temperature is 50 degree centigrade then, indicated temperature will be 55 degree measured temperature will be 55 degree centigrade minus plus 5 it is going to be 50 degree centigrade.

So, for finding out the true value, that error is always subtracted from measured value, right? And there is another term, which is known as correction. Correction is minus error that is it. So, minus of the error is correction it is also used in some references were mainly error is used.

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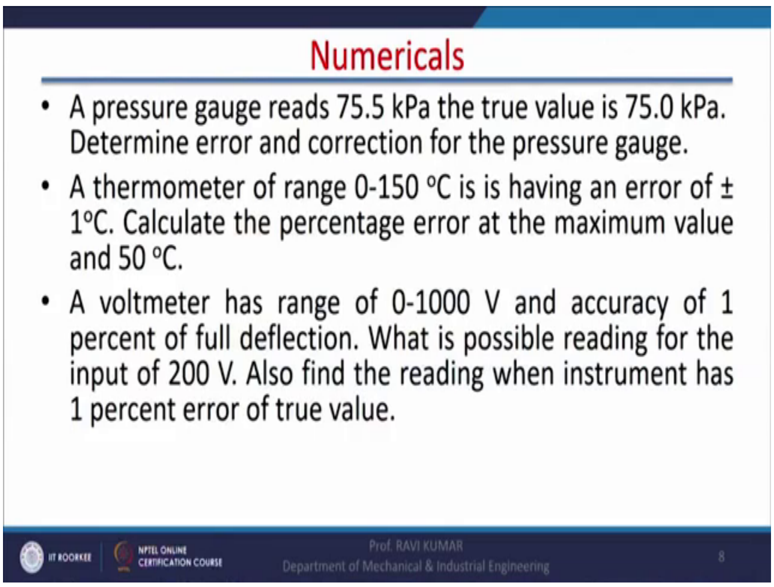

So, we will start with the numerical, which states that the pressure gauge reads 75.5 kilo Pascal, the true value is 75.5 kilo Pascal determine error and correction for the pressure gauge. So, pressure reads 75.5. So, measured value is 75.5 kilo Pascal, right? And true value is 75.0 kilo Pascal. So, error in the measurement is going to be this minus this measured value minus true value and this is going to be 0.5 kilo Pascal and it is positive correction is minus 0.5 kilo Pascal because, correction is negative of their. So, correction is 0.5 kilo Pascal.

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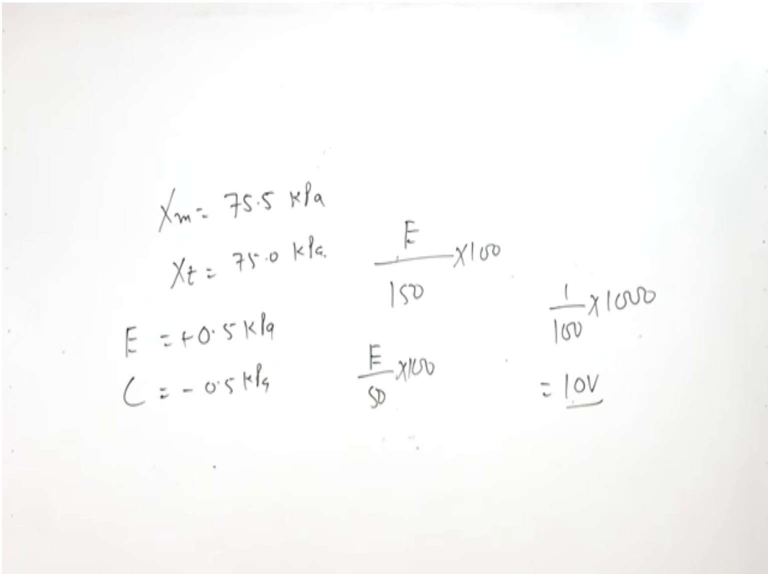

Now, other example a thermometer of range 0 to 150 degree centigrade is having an error of plus minus 1 degree centigrade. Calculate the percentage error and maximum value and 50 degree centigrade. So, at maximum value the error is going to be the error divided by 150 and at 50 degree error divided by 50 into 100, they are very simple numerical, but they develop the understanding of the subject. Now, the third one is a voltmeter has a range of 0 to 1000 volts, it is a quite large range and accuracy of 1 percent of full deflection. So, 1 percent of full deflection means, 1 by 100 into 1000 accuracy of 10 volts, right? What is possible reading for input of 20 volts sorry 200volts?

So, this is input an error can go up to 10 volts. So, definitely there is a possibility of having the reading of 200 as 210 because, direction of error is not giving. So, we can say it can be 210, right? Also find the reading when the instrument has 1 percent error of true value. So, true value means whatever reading you are taking. Now, for true value means, suppose the voltmeter reads 500 volts, right? And error is 10 volts. So, then this is going to be the percentage of true value and it is going to be 100, 1000 in 2 percent. So, in that case when we say the error percentage of true value then, we just divide error by true value and multiplied by 100 then, we get error for true value.

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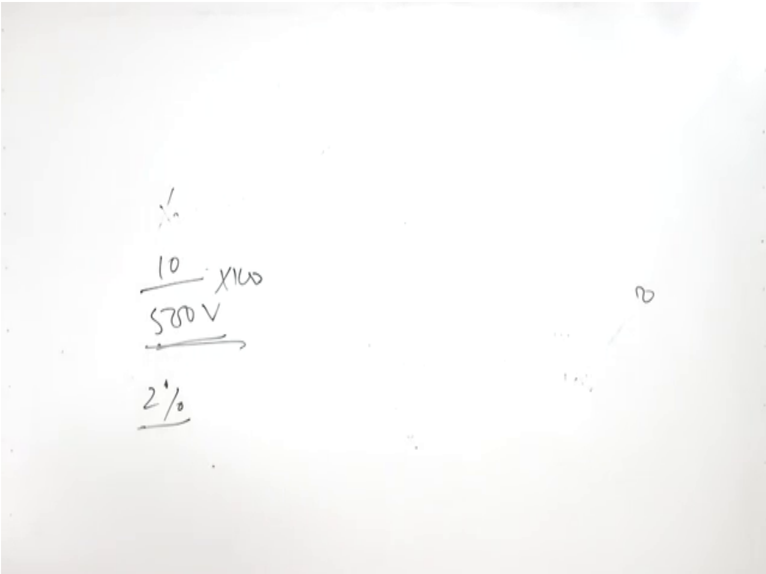

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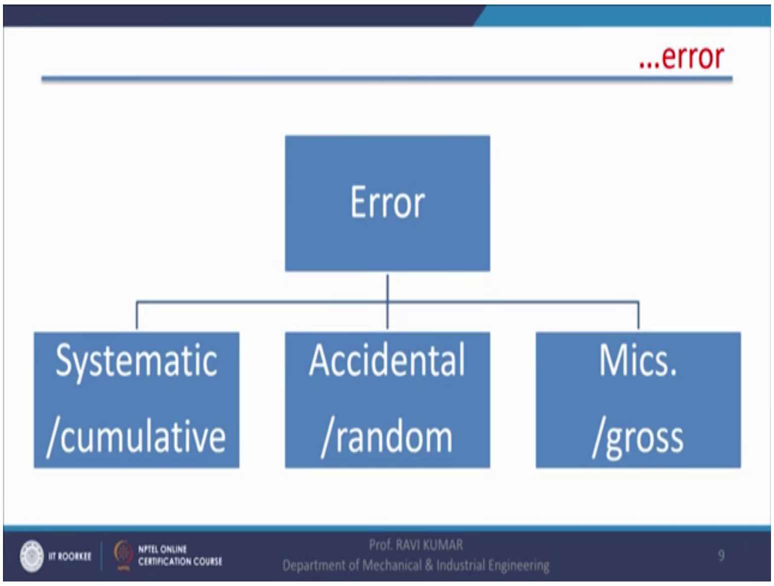

Now, classification of or there are many type of errors.

So now, we will go for the classification of errors, error can be be classified broadly classified in 3 broad categories that is error.

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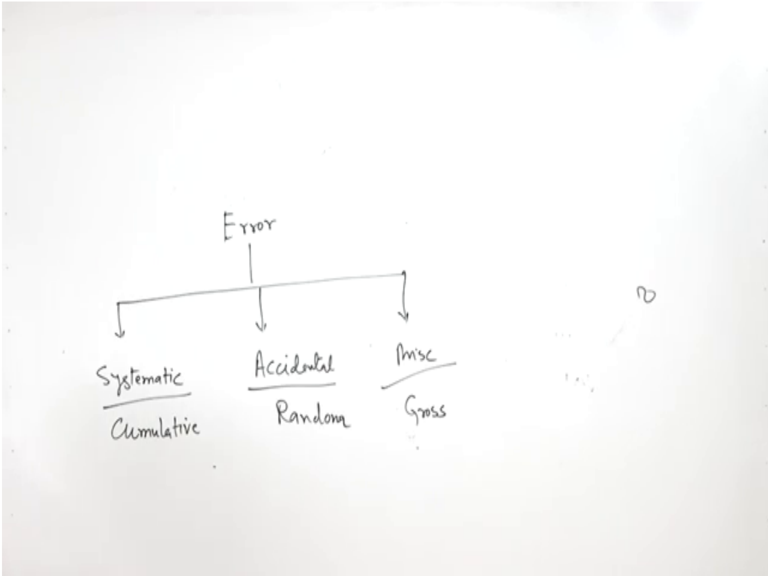

So, these 3 broad categories are number 1 systematic error, number 2 accidental and number 3 is miscellaneous errors and they have other names also systematic error also known as cumulative error, accidental error is also known as random error and miscellaneous error is also known as gross error, right? So, all these categories of the error we will discuss one by one.

So, let us start with the systematic error systematic error or cumulative error. Systematic error can further be divided in 3 parts one is instrumental error. Now, what is instrumental error? Instrumental error is the fault in the instrument or error for example, you have weighing machine there is a weighing machine and weighing machine has unequal arms, unequal arms you are putting 1 kg weight here, perhaps you will weighing goods of only 800 grams, right? So, this is instrumentation instrumental error because, there is a problem with the instruments or if you are measuring with a scale the divisions are not uniform if the divisions are not uniform, that is also covered under instrumental error.

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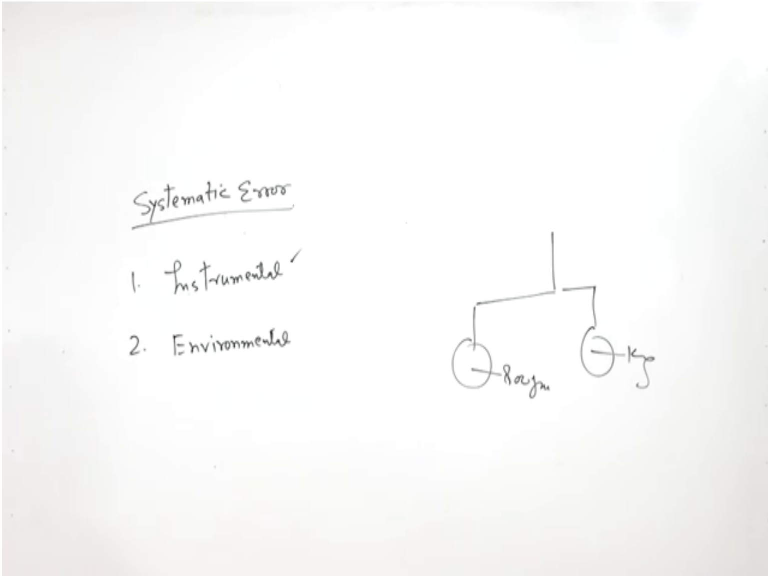

So, it is the error of the instrument problem with the instrument. Now, second one is environmental error it is the error, which creeps into the instrument due to environment for example, there is a temperature change. So, the standard length of the scale will change, that is why the measuring scales or (Refer Time: 18:49) scales are made of (Refer Time: 18:50). So, that because (Refer Time: 18:51) has minimum expansion of expansion coefficient humidity due to humidity also the instrument may change the reading. So, external environment maybe electromagnetic field, right? That will alter the reading of the instrument and this error error due to this is known as environmental error. Even there is a pressure change in the environment that also results in the error in the measurement by the instrument.

Now, third one is loading error. Now, loading error is the error when we make the measurement as I stated in the earlier lectures also.

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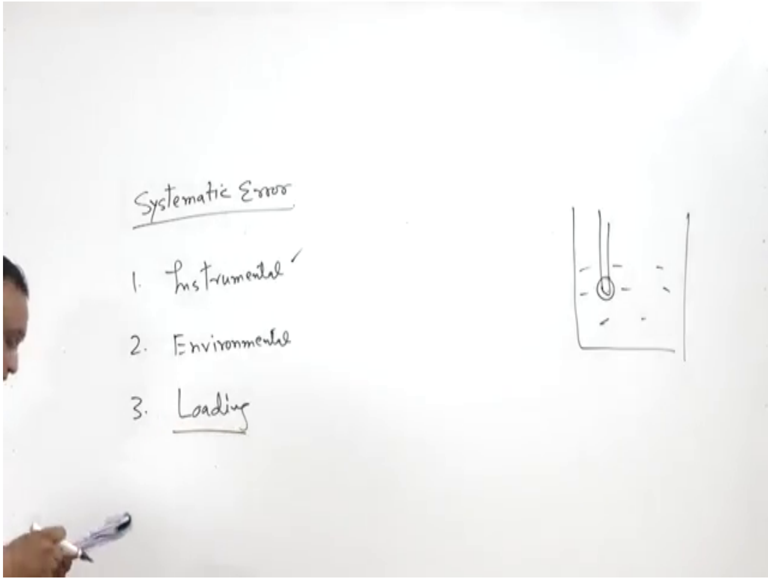

Suppose, we measure we want to measure the temperature of water in a bucket while doing that, if we will be putting a thermometer in the bucket and the bulb of the thermometer will extend certain amount of energy from the bucket. So, energy of the bucket will go down maybe insignificant, but it will go down because, certain amount of energy has been extracted from the measuring, right? And error due to this is known as loading error for example, flow metre in flow metre if we use obstruction type of flow metres orifice metre or rotometer. So, when we are putting this device into the pipeline it is obstructing the flow, right? And this is also one sort of loading effect, which may alter the flow rate itself, right? So, these type of errors are known as loading errors.

Now, accidental error is also known as compensation or it is due to lack of consistency in measurement or inconsistencies in the measurement and it can be positive or negative cumulative error is always positive error it is one direction only and cumulative error can be corrected by calibration because, we know in which direction the error is going and in subsequent readings or subsequent observations it try to accumulate it gets accumulated not tries to accumulate, but it gets accumulated that is why it is known as a cumulative error.

Now, accidental error can be negative or positive and it is also known as compensation error and due to lack of inconsistency in the instrument.

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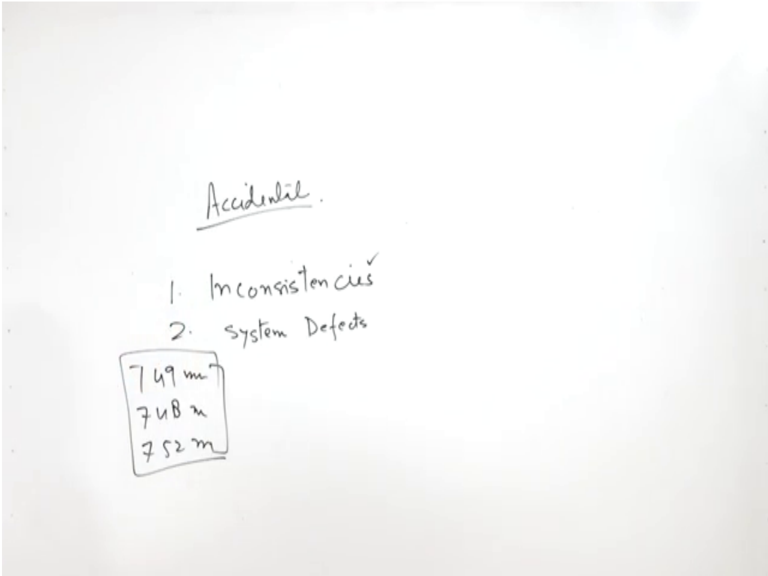

So, first of all inconsistencies, in inconsistencies in the measurement for example, I want to measure the width of this podium see if I ask you to give width of this podium in centimetres perhaps you may give 70 or 75 centimetres and repetitively, if you measure the you will be getting the same reading, but if I ask you to give the reading of this podium in millimetres perhaps first feeding maybe one 749 m m, second reading maybe 741 m m sorry, 48 m m or third reading may be 752 m m. So, this is inconsistencies measurement. So, due to these inconsistencies the error, which is creped into the measurement is known as accidental error.

Now, system defects this is also accidental error, system defect for the over their use some backlash may develop in a mechanical measuring system, right? So, this backlash will cause system defects second thing is misalignment of the shafts if there is a (Refer Time: 22:59) shaft or any 2 component if there is a misalignment, that also will cause accidental error and it can be positive or negative I mean it is in cumulative error it is only one direction, but this can be this error can be bidirectional error.

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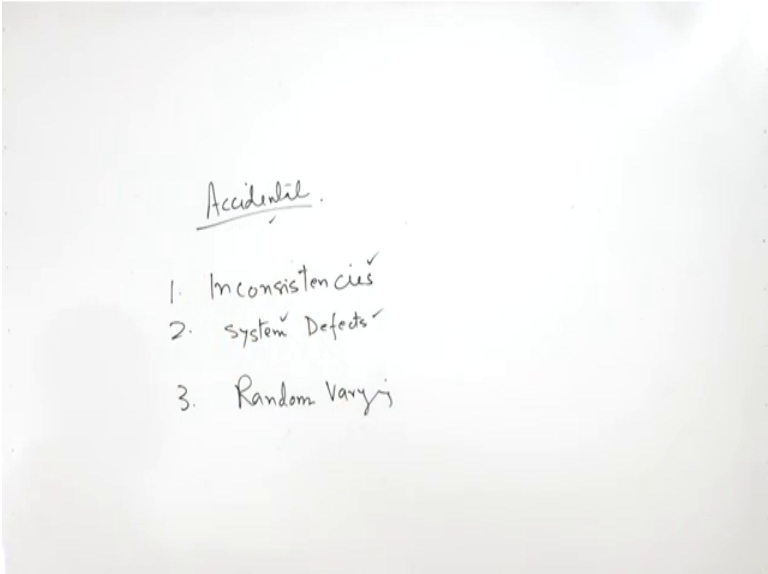

Now, third is randomly varying parameters this is third one is random, random varying parameters for example, you are making one measurement there is a fluctuation in voltage, that is random randomly varying parameter and this error will creep into the measurement or vibrations on the table or something vibrations are generated or some all of a sudden there is an any other parameter, which is which has unexpectedly varied and caused the influence of the measurement. So, this is known as error due to randomly varying parameter accidental error is also known as random error it is also known as random error.

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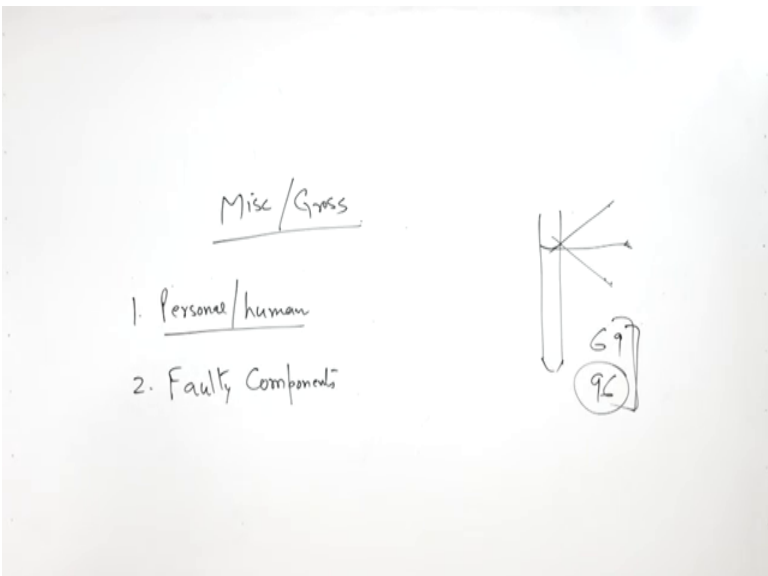

Now, third type if error is miscellaneous or gross error or gross error. Now, gross error again has 3 component one is personal or human error. Now, human error means suppose you are conducting some titration and instead of you have to your eyes have to be in at the same level with the meniscus, right? And if you are looking at the reading from here, you may develop some error or you are looking from the top, that will develop some error or instead of reading 69 you read 96 this is also human error. So, on errors due to limitation of human faculties is known as personal and a human error and they are sometimes they are gross error suppose temperature is 60 (Refer Time: 26:28) and by the mistake you note 96, right? So, all the calculations will change. So, this type of error is known as miscellaneous or gross error this is due to personal human limitation faulty components.

Faulty components means, suppose you are measuring flow rate using a bucket. So, you have put bucket on a weighing machine, you have put a bucket on the weighing machine, right? And water is coming to the bucket, right?

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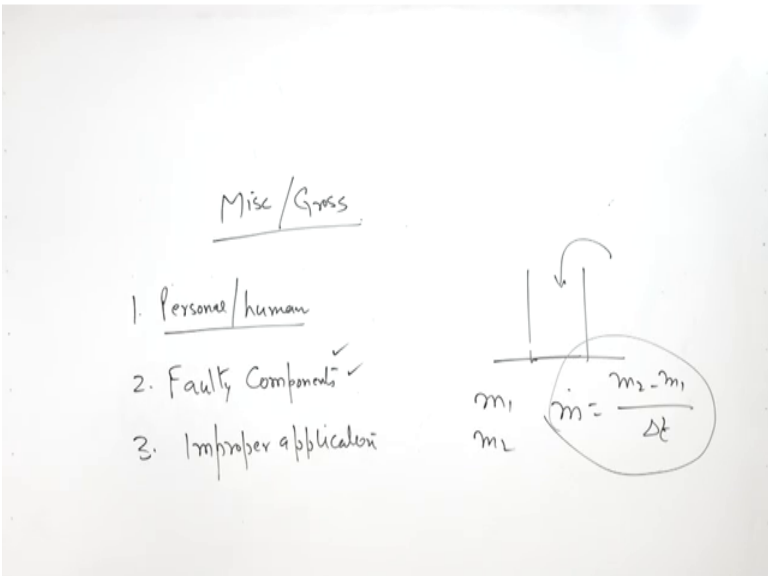

So, you have taken m 1 mass of the empty bucket noted some same maybe for 1 minute or 2 minutes or 60 or say let us say, 100 seconds after 100 seconds mass of the bucket is m 2 then, flow rate is m 2 minus m1 divided by delta t this is how we will do the measurement. Suppose there is a leakage from the bucket, that is a gross error I mean the leakage from the bucket then, your all calculations will be grossly changed, right? And this type of error is known as (Refer Time: 26:52) due to faulty components there can be many examples (Refer Time: 26:56) electric same in the case in the electrical appliances also suppose there is a leakage of current, right? And you are doing measurement and there is a leakage of charge of the current then, your measurement will also be altered.

So, this type of error is due to faulty components and third one is improper application. So, every instrument is designed for a particular range of measurement or particular type of measurement, if you are doing improper if proper application is not made of the I will give you an example for example, you have a voltmeter there is a voltmeter and it reads 0 to 100 volts, I want to measure input of 1 volt or 0.5 volt.

This is improper application of the instrument, if I want to measure 1 volt I should have range of 0 to 3 volt or 0 to 5 volt then, I will get proper measurement of 1 volt, but if I am using voltmeter of the range of 0 to 100 volts and I want to measure 1 volt definitely a lot of error will creep in, and that is also known as miscellaneous and gross. So, these are the different type of errors we have discussed so far this is all for this lecture remaining static characteristics we will be covering in the next lecture.

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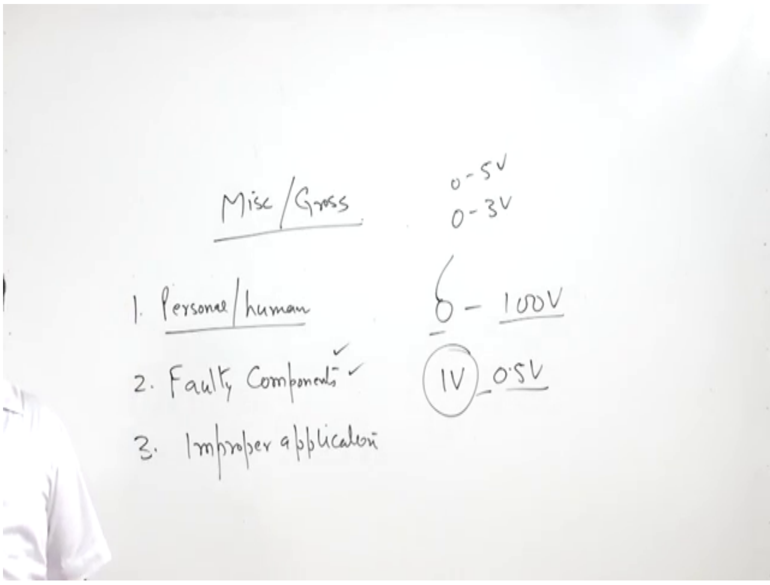

Thank you very much.