Experimental Methods in Fluid Mechanics
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Lecture – 07 - Dimensional measurement Gauge blocks, The pneumatic displacement gauge

Good afternoon to all. I welcome you to the session of Experimental Methods in Fluid Mechanics.

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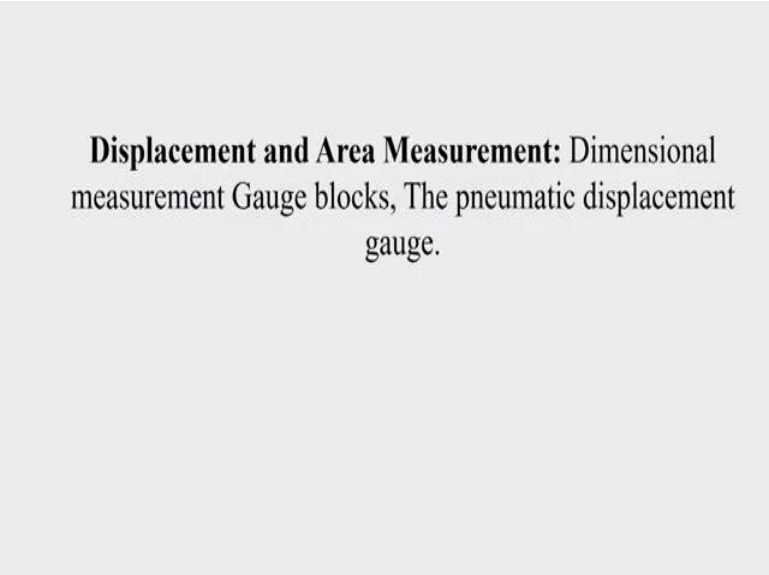

Today, we will discuss about displacement and area measurement, this is another module of this course but before I start discussing about this, I will take 5 to 10 minutes to discuss about the impedance matching that we could not cover in my last lecture.

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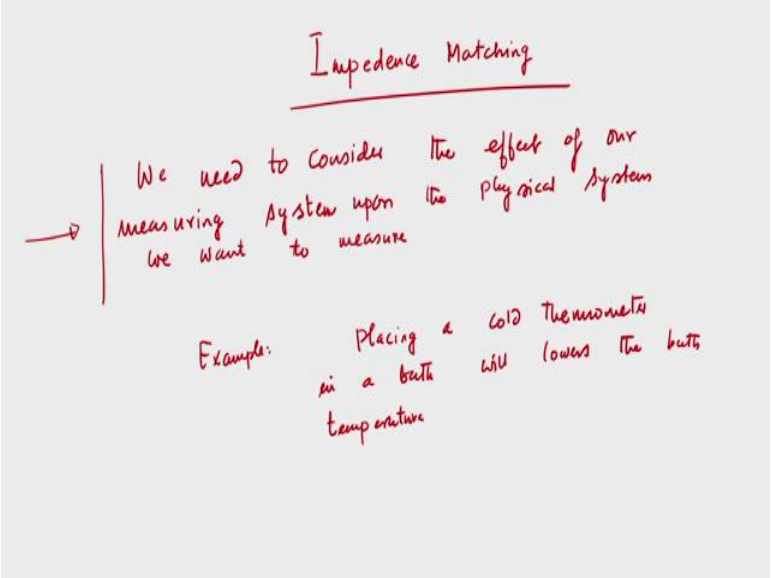

So, probably if you can recall that we have discussed that impedance matching to know that what is that and why you should consider this, at least we should know that this impedance matching, impedance matching it is very important because at least we should know effect of our measuring system on the physical variable that we are going to measure, that is very important.

Again I am writing, though I wrote this statement in my last lecture, but even I am writing that we need to consider rather we should know about this, we need to consider the effect of, effect of our measuring system. We will discuss this again taking an example, the effect of our measuring system on the physical system we are going to measure. So, effect of our measuring system I can say upon the physical system we, we are rather we want to measure.

So, this is very important at least if we know this then perhaps we can understand why you need to have impedance matching, this, we should, why you should have this impedance matching while you are measuring any variable using any equipment or any device or any instrument. So, at least I can give you an example, say, if I place a cold thermometer in a bath. So, placing the cold thermometer in a bath definitely will lowers the bath temperature. So, we should, we need know, we need to know that, that if we place a cold thermometer in a bath then definitely it will try, it will lowers the bath temperature.

Similarly, an accelerometer will increase the mass of the system and that will change, I mean how it will, another important thing is accelerometer will increase the mass of the system changing how it will vibrate. So, these two are example I have given you that if we place,

placing a cold thermometer in a bath will lowers the bath temperature. So, that is what very important that if we would like to measure using a thermometer of a, of the temperature of a liquid that is there in a bath.

Now, if the thermometer that we are going to take rather we are going to consider for that particular measurement, if it is cold then obviously it will lower the temperature. Similarly, now, before I go to take this example this impedance matching this is normally encountered in electrical measurement system but it is equally important for the mechanical measurement systems as well.

So, now keeping that in mind at least we should know what is impedance matching and perhaps I am trying to explain now with a small example and what is its effect and if we do not know a priori about this then what will be the consequence that will be clear now. Now, say, many a times I will take an example of electrical measurement system, say, when you want to make measurement of voltage.

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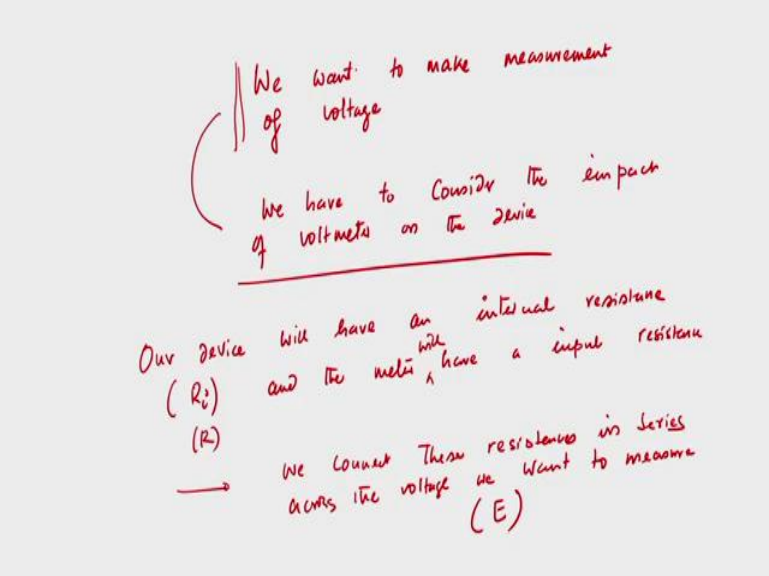

Say, we want to make, we want to make measurement of voltage is very important, then we have to consider the impact of voltmeter on the device. So, if we would like to really make measurement of voltage, then we need to have one voltmeter. Now, we need to consider rather we have to consider, we have to consider the impact of that voltmeter, that impact of voltmeter on our, on the device because now our device will have an internal resistance.

So, basically what we would like to measure? Drop in voltage across a device and what we need to do that device rather our device will have an internal resistance. So, say our device will have an internal resistance. Say, R i and the voltmeter that we need that is also having because voltmeter we need to know the drop in voltage across that device. So, now the voltmeter will have an input resistance, so the voltmeter and rather we can say the metre have a input resistance.

So, say this is R, so now, then from this example perhaps I will try to explain why you need to have impedance and what will be its role. So, it is clear that we would like to measure voltage across a device, the drop in voltage across a device, if we would like to measure that then we need to rely on the voltmeter. So, now whenever we are measuring that drop in voltage across the device, then we can assume that the internal resistance of that or rather our device is R i and the metre have will, rather metre will have an input resistance R.

So, now what we do normally? We connect these resistances. So, next I am writing, we connect these resistances, we connect these resistances in series across the voltage we want to measure, we want to measure. Say, that voltage we want to measure that is E, that is our objective is.

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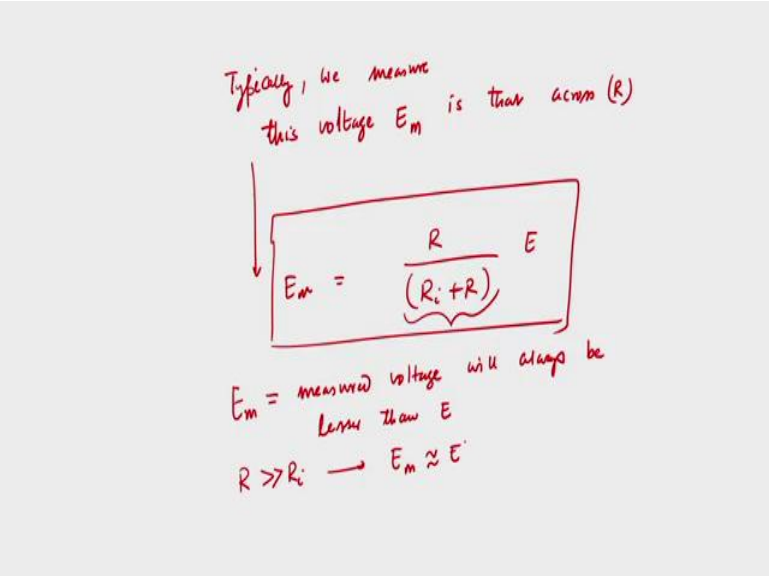

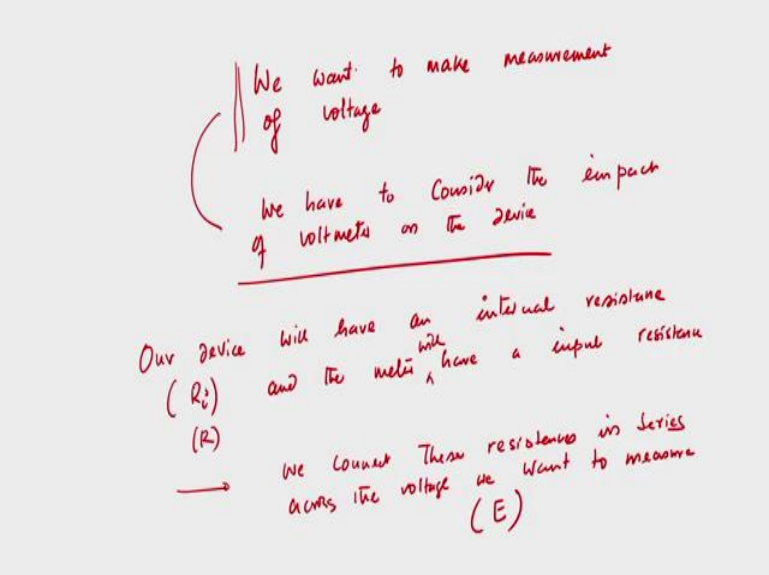

And, now say, typically the voltage we measure is that across the resistance R because so I am writing typically, typically we measure this voltage E, we ignore the internal resistance. So as if we are measuring voltage say E m is that across R, is that across R, that is the resistance of the rather input resistance. Now, so this measurement E m, if I calculate in since they are, both the resistances are placed in series or connected in series, then definitely it will be R by R i plus R into E.

So, now that is, if I go back to my previous slide that we want to measure E, we connect the resistances across the, across series and we would like to measure voltage E, but typically we measure voltage E m and is that across R. So, now E m can be written, is, that equal to R into E divide by R i plus R. Now, from this expression what can I say that our measurement E m will be always, because R i that is the internal resistance of the device of our device that will increase the resistance that is R i plus R i over here.

Now, so our measurement will be always less than the actual voltage. So, maybe we would like to measure voltage E but we are getting E m and from this we can see this E m that is measured voltage will always be lesser than E. Now, what we have seen that the measured voltage will always be lesser than E. However, that as R becomes much larger than this R i, so R i is the internal resistance as if we are measuring the voltage which is across the, across R that is the metre, metre resistance.

If R i is much larger than R i then you will, this E m, so if R is much larger than R i then E m will approach rather E m will, E m approaches E closely, it becomes closer to E. Thus, that means from this discussion what we can conclude that we would want to have the input

resistance much smaller than, much larger than the internal resistance of the device. That means, we need to put a resistance while measuring this voltage, that input resistance should be much larger than the internal resistance of the device.

Now, otherwise we cannot, we may not get the correct results. In that case E m will certainly differ from the actual voltage that we should have. Now, see, this is all about the voltage measurement, as I said that normally impedance matching are encountered in electrical measurement system but these aspects, this aspect becomes equally important for mechanical measurement system as well.

Now, if you would like to measure power or current, again, require different impedance matching condition, so this is the impedance matching condition what that the resistance, input resistance should be much larger than the resistance, internal resistance of the device, otherwise we should not have, we may not have the, otherwise we do not have the correct or accurate prediction.

And for the similarly, for the current and power measurement different impedance matching conditions will be there but the idea is same. And if we would like to really measure current, the situation regarding measurement of current is different because we would want zero input impedance to insert the current was not attenuated, the measured current was not attenuated.

So, what we have understood that depending upon the measurement, measured I mean the variable we are going to measure and whether that, I mean knowing that the equipment which you are using to measure, whether its effects on the physical system, we need to know that we that what are the things rather what are the precautions we should consider while measuring.

So, with this next I will go to discuss about the next topic that is the, that is the next module that is very important that displacement and area measurement. So, initially I am trying to discuss a few things which are very important to know the measurement techniques which are largely related to flow measurements, flow variable measurements. So, these are the basically recapitulations of several issues which are directly related to the measurement techniques.

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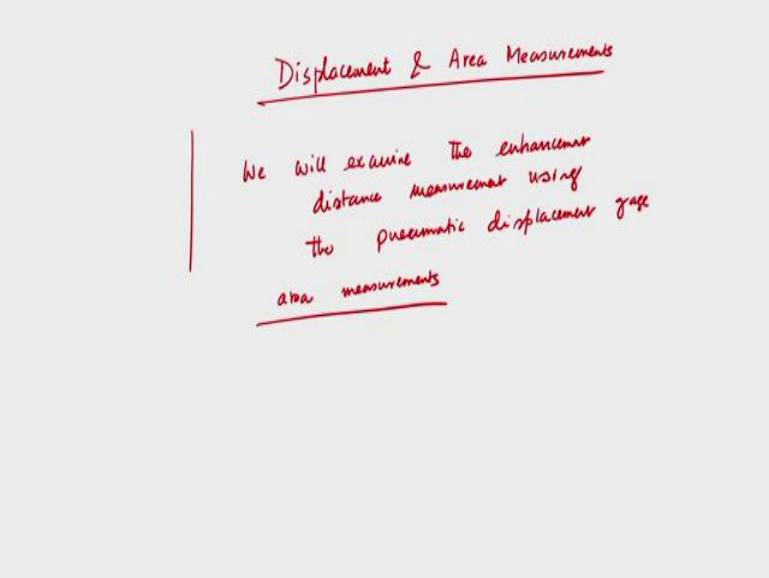

So, now we will discuss about displacement and area measurement. See, in this module we will try to examine the enhancement area measurement, enhancement distance measurement. Displacement measurement this is the broad term, largely we will be focusing on the distance measurement. So, through this model rather through this module we will try to examine the enhancement of distance measurement and then area measurement using pneumatic displacement gauge and the gauge blocks.

So, largely we will try to, what we will do? We will examine the enhancement of, enhancement distance measurement rather I can say, okay fine enhancement, distance measurement, distance measurement using the pneumatic, pneumatic displacement gauge and of course area measurement using several other techniques we will discuss subsequently area measurements.

So, again I am telling that accurate measurements be it distance, be it area or (dimen) displacement, so displacement or area that is basically dimensional measurement. So, accurate measurements are very important for both industrial and experimental applications. So, we have seen that many a time we use many types of, different types of scales, tyres, calipers, micrometres for measurement of displacement, small distance and then also Vernier gauge.

But, it is very important to know that the accuracy, precision of those instruments are very important because and particularly for the small measurement. So, if we would like to measure very small distance, then how can we measure and if we would like to measure then

what are the devices available, what are the equipments available that is what we will discuss today.

Now, say, as I said that distance measurement or area measurement they are accurate measurement of distance is very important, as I said that they are important for both in industrial and experimental applications. So, accurate distance measurement rather measuring instruments we know that micrometres then other things, other devices that is what I said that calipers are there. But probably using micrometre, we can have accurate measurement, but that micrometre when you are using for accurate measurement that must be calibrated periodically as there will be a chance of having error in the measured data.

So, accurate distance measuring instruments such as micrometre for example, should be calibrated periodically because there will be a fixed error that changes with use. So, if we do not calibrate them periodically then again we may come up with our, I mean measured data which is not correct.

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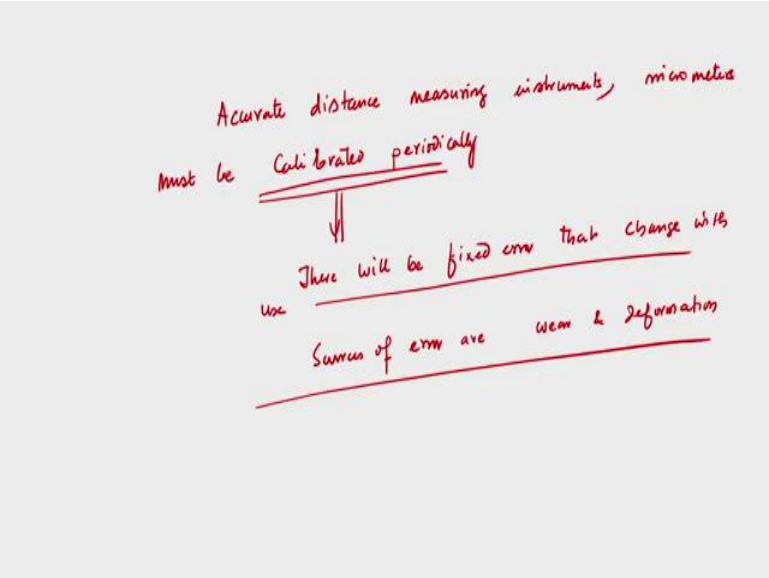

So, I am writing that when we talk about distance measurement if we know that accurate distance measurement measuring instruments, say for example, micrometres, micrometres, so accurate distance measuring instruments for example micrometres are, there are many, so those instruments should be calibrated periodically. So, I know rather I can write, must be calibrated periodically because, why you need to have this product calibration?

Because there will be fixed error that changes with use, because we will be using this repeatedly, continuously. So, this error arises due to what? So, if we keep on using a micrometre for measuring distance, so one important thing is that, that is what I am discussing that when we talk about, so distance measurement is very important both in industry and experimental application.

Accurate distance measuring device, there are many instruments, there are many devices like, for, say for example, micrometre is one of them. But those devices must be calibrated periodically, why? Because there will be fixed error that changes with use because we will be using continuously. Now, the sources of error are is, the sources of error are, because we will be using all our mechanical, instrument mechanical device, so wear and deformation.

So, the sources of error are mechanical wear and deformation. So, considering this we need to calibrate then periodically. Now, with this we will now see that if you really need to have a very small measurement in addition to the micrometres there are, there is another device which is known as pneumatic displacement gauge. So, today I will discuss about that, that knowing that, that we need to calibrate those accurate measuring devices periodically because of they are used because of the fact that they are used, they are used continuously and because of that mechanical wear and deformation leads to fixed error in the measurement, process of measurement system.

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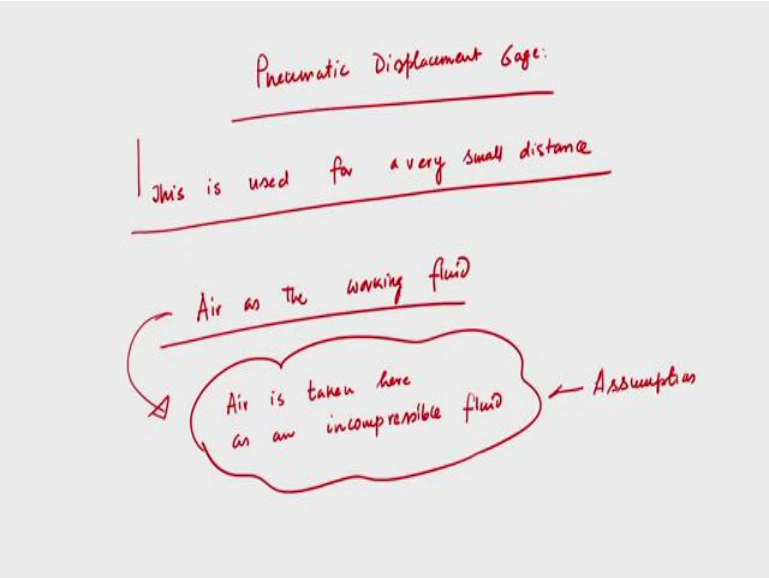

Now, in addition to that you know that accurate measuring device micrometre, another device that is what we will discuss, that is called the pneumatic displacement gauge. So, pneumatic

displacement gauge, pneumatic displacement gauge. This gauge is essentially gives us rather used for very small measurement. So, this is used for a very small, very small distance and it relies on again because in the since this course is on experimental methods in fluid mechanics, so basically this gauge use air as a working fluid, this gauge use air as a working fluid.

And then we will see now from the schematic of this gauge that the principle of measuring small distance or small distances using this device, I mean what is the basic principle? So, basically pneumatic displacement gauge the word pneumatic, that basically it tells that it is having air as the working fluid and this fluid is taken through a special type of environment system that is what we will discuss.

But while used, while we are using air to measure small distances using pneumatic displacement gauge we treat air as an incompressible fluid. So, here we treat air, this is an assumption but the validity of the assumptions can be found in many textbooks and Holman or even classical Fluid Mechanics textbook be also, so air is taken here as an incompressible (liq) incompressible fluid.

So this is one of the important, one important assumption that we need to consider for measuring small distance using this device or garage. So, this is assumption. As I said that the validity of the assumptions can be found in textbook like Holman, Experimental Methods and many other text books which are focusing on the, on several experimental methods. And considering that assumption now we will slowly move to see that how, what is the working principle of this device and by how it measures a small distance.

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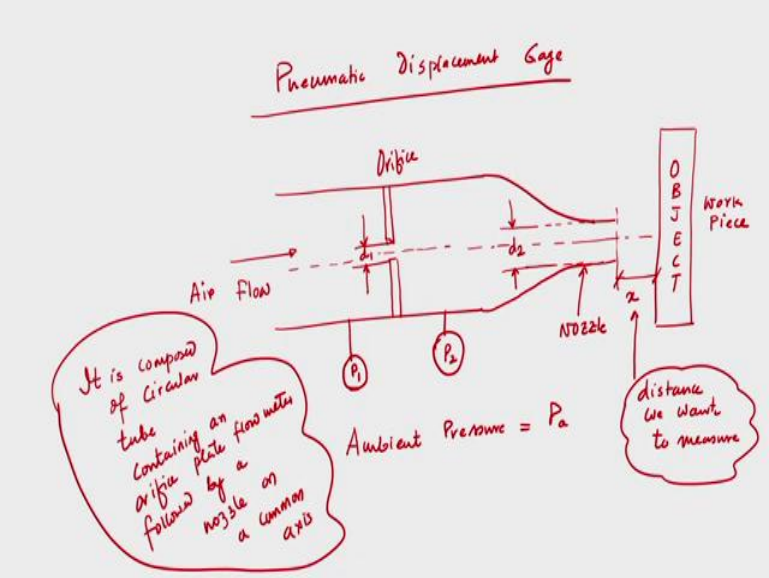

So, first of all I will try to draw a schematic. So, I am now trying to draw schematic, again I am writing pneumatic displacement gauge. So, I am now, and say this diameter is d1 and this diameter is d2 and so we have a cylindrical shaped exit just nozzle, so this is basically nozzle, safe portion and we are having over here one object, so this is object and work piece we can say, say this is also work piece and say this distance that we would like to measure that is say x.

And say we are having flow of air, flow or I can write air flow. Now, we need to have gauge pressure, I mean pressure say this is one pressure gauge P2 and this is one P1, so this is very important that we will measure this and let us say ambient pressure is the ambient pressure is equal to Pa. Now, so as I said that this can be used to measure small distance x, so basically this distance we want to measure, so that is the distance we want to measure. Now, it is composed of a circular tube, so I am writing it is composed of circular tube containing an orifice plate, containing orifice plate flow metre followed by a nozzle on a common axis. So, this is the structural shape, so that is what I have written over here, that the axis is common. So, basically this is the axis.

So, it is composed of a circular tube containing an orifice plate, say, this is the orifice, this is orifice plate and orifice plate flow metre and followed by nozzle on the common axis. Now, see the gauge will be placed normal to the work piece, so the work piece is extreme right hand that is extreme right side that is what we have drawn object or work piece and gauge is

placed normal to the work piece such that the nozzle is at a distance x from the work piece and this distance that is what we like to measure x.

So, when we are going to measure x, again with this gauge there are two pressure gauge, there are two different pressure gauges are connected to this displacement gauge P1 and P2, one is placed at the upstream of the orifice, and another is the downstream of the orifice. So, placing these two pressure gauges and now having flow of air through this orifice metre then nozzle we can calculate rather we can measure the distance, which is very small.

Now, we will discuss because again when we will be discussing to know the working principle of this displacement gauge, we again need to know the basic Fluid Mechanics whatever we have learned. So, essentially what we have to do? We have to measure flow rate through the orifice, as well as flow rate through the nozzle. And we have considered one assumption is that air is considered to be an incompressible fluid. So, I mean the flow rate we can equate through the orifice, as well as through the nozzle.

Now, from there with some mathematical manipulation we will see that how we can arrange those things and we will come up with equation, that will give us you the relation between x and the measured pressure through the gauges P2 and P1. So, just I am telling you, what we will do? The flow rate through the nozzle will be related to the displacement x and now the flow rate is again linked with the measured value of pressure using the gauges placed over, placed in the pneumatic gauge.

So, indirectly we can relate what will be the measured distance x through the measured value of pressure using the gauges and from there we can say that what will be the, so by knowing the, by measuring the pressure we can say that what will be the displacement. So, again I am telling, we need to know that flow rate through the orifice metre and fluid through the nozzle and after calculating the fluid through the orifice metre and flow rate through the nozzle we will now, we will try to, we need to do few algebraic steps and then we will try to see that how we can relate x in terms of the measured value of pressure using the gauges.

We will discuss this issue in detail again, then, I mean how we can relate this x in terms of measured value of pressure and that work, exercise we will do in the next class. Thank you very much.