Mechanical Measurement Systems
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Lecture – 33
Pressure Measurement

Hello. I welcome you all in this course on Mechanical Measurement Systems. And today we will discuss about the Pressure Measurement.

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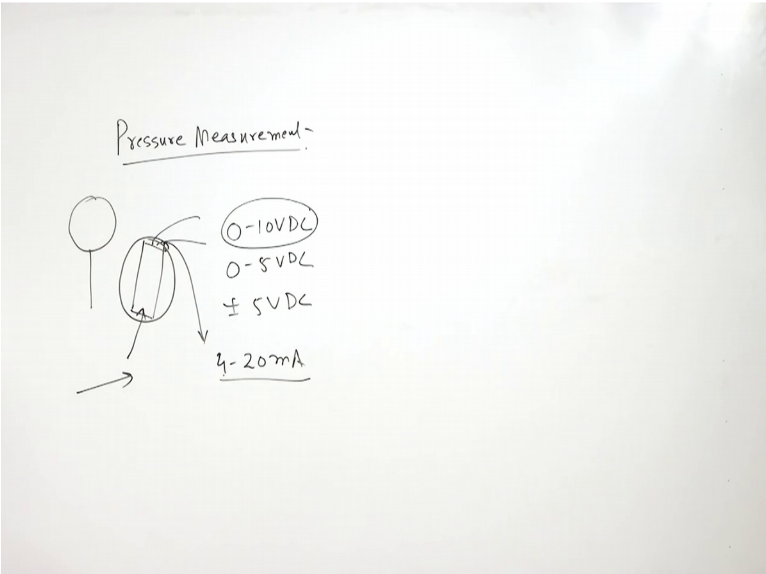

And we will discuss different types of pressure measuring devices. So, pressure measurement. Pressure measurement is a very important activity in any research organization or in any industry. In most in most almost in all the industries it is required that pressure be measured. And normally dial types of pressure gauges are used in the industries for the measurement of pressure or pressure transducers are used. These transducers if you go by input and output input to this transducers is pressure and output get in two forms either 0 to 10 volt DC normally. It can be 0 to 5 volt DC also or plus minus 5 volt DC also.

And if the pressure has to be transmitted to a far of location then the only ah current type of output is preferred that is 0 4 to 20 millions of output. But if we go the by the process through which the pressure is now this output from the transducer, goes to the (Refer Time: 01:54) system and this output range is calibrated for input pressure range on a linear scale and that is how the pressure measurement is done. Now in this cylinder or a box or a entity there are sensors and there is a lot of electronics, which converts the pressure signals to the voltage or current signals. Now today we shall start with the basic measurement devices, and before we go to the pressure measuring devices I will give you slightly a slight idea about pressure measured in different units.

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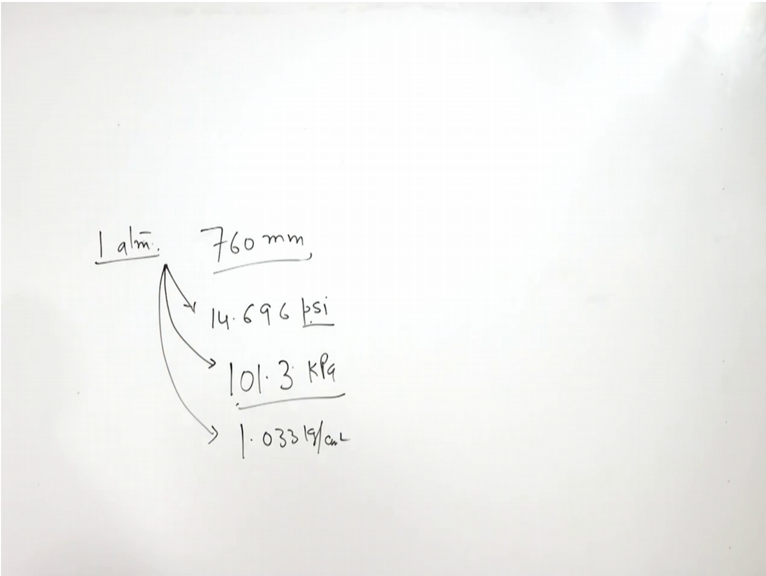

The normal atmospheric pressure is 760 mm coulomb of the mercury pressure equivalent to 760 mm column of mercury, and in inch point system of atmospheric pressure is 14.696 PSI Pounds per Square Inch and when we deter when we express 1 atmospheric pressure in si system it becomes 101.3 kilo Pascal right where it is expressed in NKS system in kg per centimeter square, 1.033 kg per centimeter square. Now there is another unit of pressure is eta eta.

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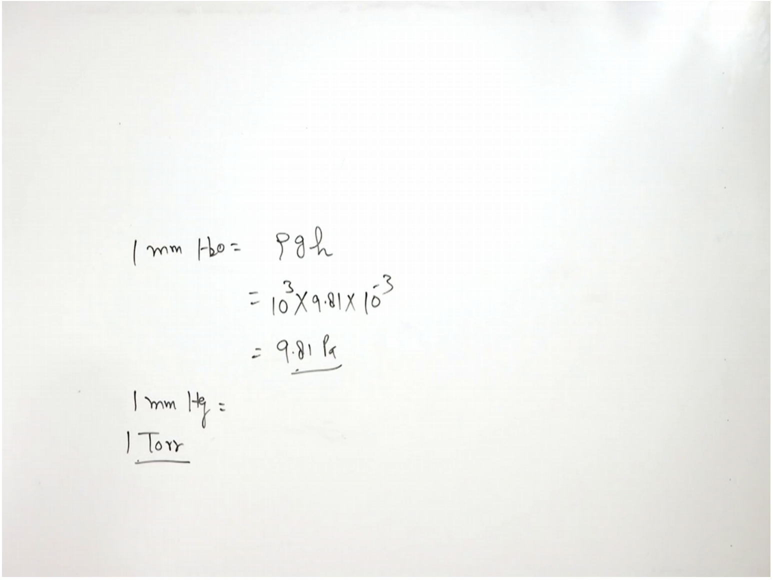

And 1 eta is 1 kg per centimeter square. Now pressure is also expressed in terms of a millimeter coulomb of water. So, 1 millimeter of water is equal to rho gh.

Let us take trans t 10 to the power 3 g is 9.81 and height is 1 mm. So, 10 to the power minus 3 it is 9.81 Pascal; 1 mm of mercury also expresses the pressure and 1 mm of mercury is 1 Torr it is ex written as 1 Torr vacuum is or EPS very low absolute pressure is measured in term of Torr.

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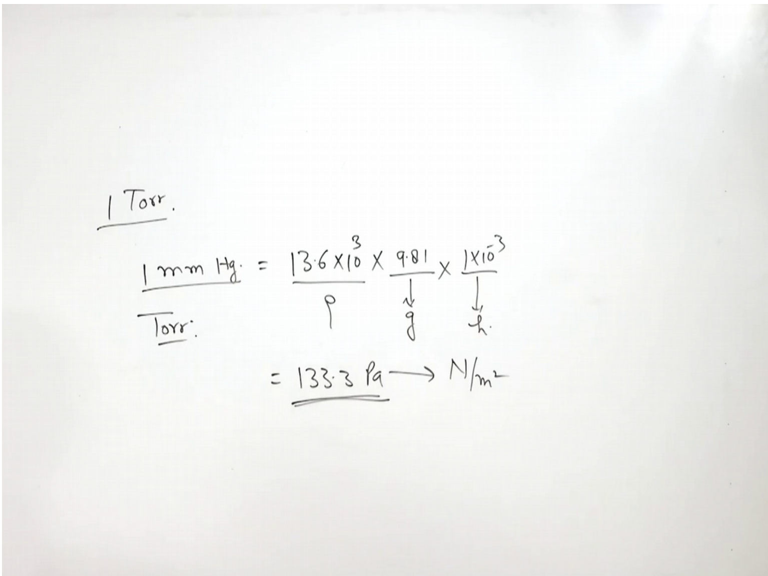

Now 1 Torr this is also unit of pressure. So, 1 Torr is equal to 1 millimeter of mercury. So, bun 1 millimeter of mercury is equivalent to relative times to the mercury is 13.6 into

10 to the power 3 this is rho, g is 9.81, this is g into h into 10 to the power minus 3. And if we take the product of this we will get 133.3 Pascal's. Pascal is Newton's per meter square; so very low pressure or the vaccum is often expressed in terms of millimeters of mercury or Torr. Now classification of pressure the pressure is also expressed in terms of absolute pressure, gauge pressure and vacuum.

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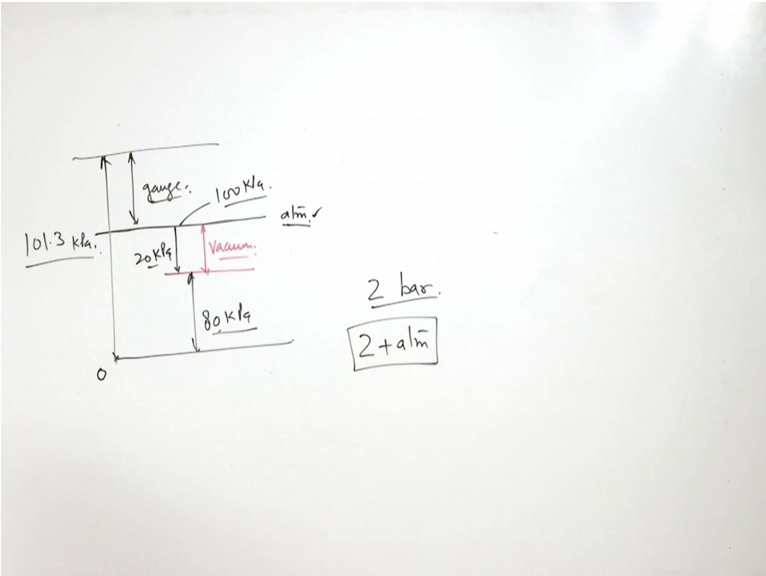

Suppose there is absolute vacuum the pressure is going to be 0 because they are no mal molecules to ah transfer the momentum. So, at 0 at absolute vacuum there is no pressure, and then it is atmospheric pressure this is atmospheric pressure. So, atmospheric pressure may vary depending upon the location, temperature and it is dependent on many factors. So, were on the earth you are located, what is the temperature of that particular location and geographical condition, this atmospheric pressure is decided.

And it varies I mean day to day basis even our new variation is observed in atmospheric pressure though it is very less, but it is also with atmospheric pressure goes down significantly, then there is inflow of the wind and storms takes place. So, we will not discuss here about the weather conditions. Now this is atmospheric pressure let us say for beam sea level 101.3 kilo Pascal and now above this pressure measured above this pressure is gauge pressure.

So, normally the pressure indicated by the pressure gauge is the gauge pressure. If you want to make use of pressure will have to add the atmospheric pressure. For example, stream is available at gauge pressure of 2 bar. It is the steam available at 2 bar plus atmospheric pressure that is the absolute pressure of steam, and this pressure has to be taken in into account while calculating the thermo physical properties or in any calculations related to the steel. So, whatever is indicated by the gauge has the atmospheric pressure has to be added and this will give the absolute pressure. Now other term this is absolute pressure gauge pressure vacuum.

So, pressure below the atmospheric pressure is known as vacuum. Suppose pressure below the atmospheric pressure is let us say: 100 kilo Pascal. If there is a vacuum of 20 kilo Pascal, it means the pressure is 20 kilo Pascal below the atmospheric pressure or absolute pressure is 80 kilo Pascal. There is a static pressure and dynamic pressure also while measuring this system static pressure is suppose for example eh in case of putative we have already used that right.

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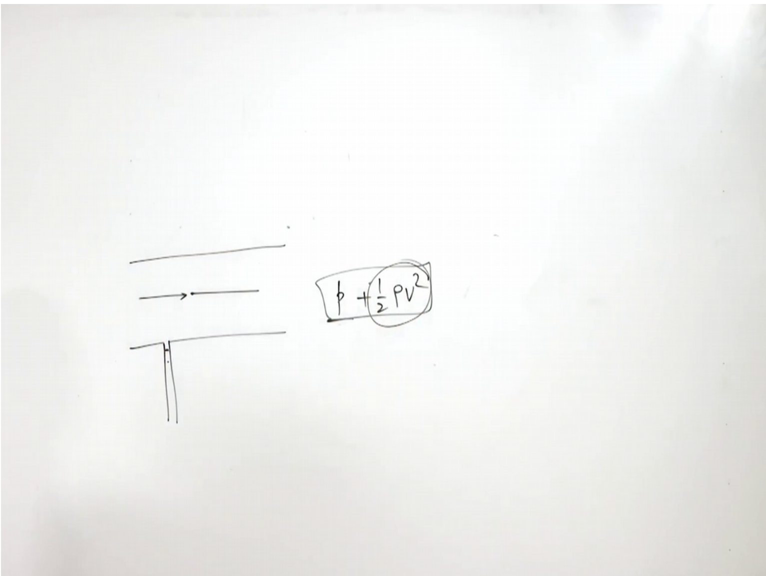

So, pressure here from this coulomb was coming static pressure and stagnation pressure due to stagnation effect of the velocity because here, the pressure p by rho. The total pressure is going to be p plus half rho v square, this will be the total pressure here and this is this known as stag stagnation pressure or this is ah static pressure and difference of this will give velocity head of the fluid.

Now their pressure measuring instrument which are used for different range of pressure measurements for example, instruments for 1 mm of mercury 2000 atmospheric pressure.

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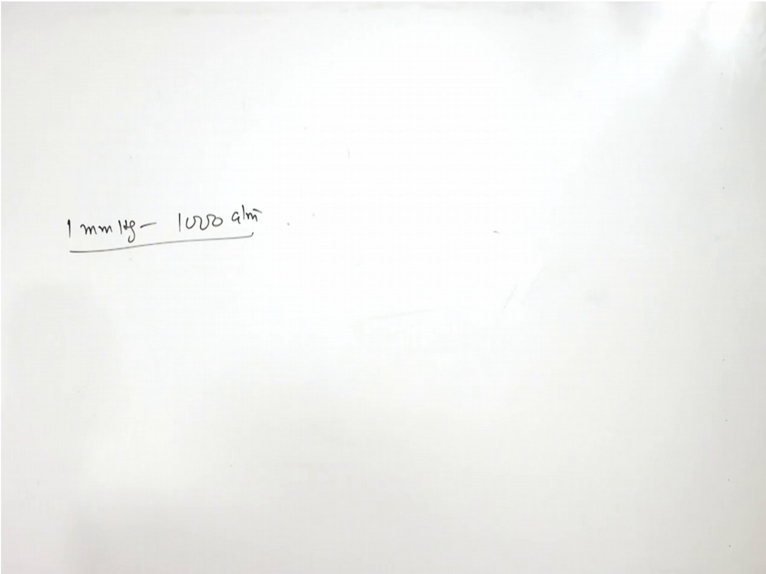

The normal pressure gauges and transducers are used for this purpose, and they are sort of they use broaden tubes or diaphragm type of gauges for the purpose of measurement they are the sensing elements. When it is ultra high pressure for ultra high pressure we can go for broaden tubes and resistance pressure gauges are used for ultra high pressure with the pressure exceeds the 100 1000 times of atmospheric pressure.

When the pressure is below 1 millimeter of mercury; for below 1 millimeter of mercury (Refer Time: 10:24) tubes are ah or manometers are used manometers are used on the pressure measurement and when the pressure is ultra low then McLeod gauge and Peronei gauge are used for the pressure measurement. So, we will start with the manometers which is very simple and common device for pressure measurement manometer.

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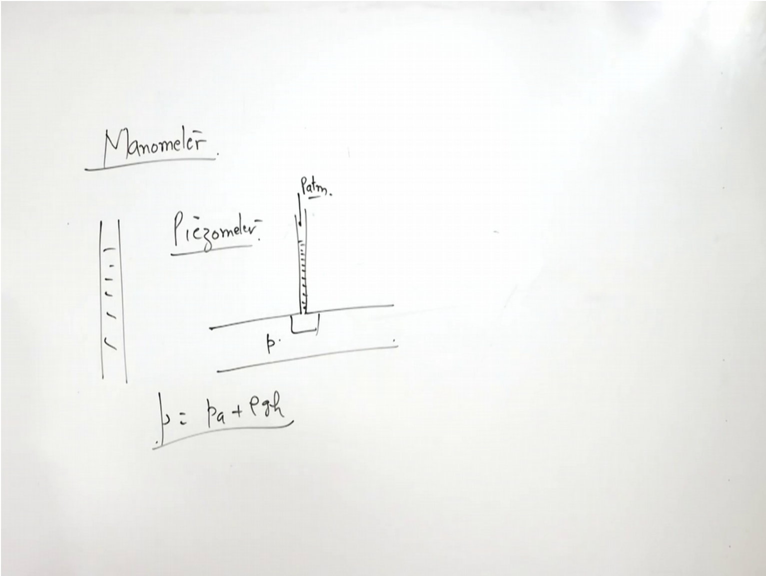

In manometer will start with it is the manometer is a device, when the pressure is measured with the balance of vertical coulomb of the fluid. Now the simplest 1 is Piezometer. For example, there is a flow in pipe at one opening of pipe you put a vertical transparent tube, the gauge pressure equivalent to pressure inside pipe will be compensated by the head the water coulomb in this tube or liquid coulomb in this tube or this is P atmospheric. So, just we will add rho gh in P atmospheric will get the total pressure inside the tube.

So, p is equal to pa plus rho gh, but the Piezometer cannot be used for the gases because gases do not have free surface and the second drawback of this is it cannot be used in the case of vacuum. Vacuum cannot be measured with the help of Piezometer. Another type of pressure measuring device is U tube manometer and which is very popular.

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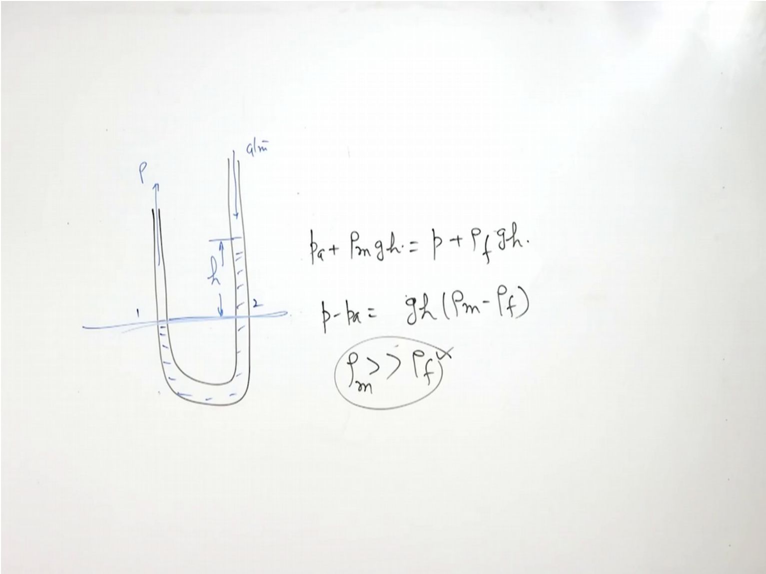

In U tube manometer, it is a U tube normally filled with mercury or any other fluid right. So, it is filled mercury or with any other fluid, suppose at this side is connected to the pressure your pressure has to be measured, this side is open for atmospheric here and this head h. Now pressure at this plane is same on the u tube. So, if we take pressure 1 and pressure at 2. So, pressure at 2 is p atmospheric pressure plus rho mercury gh, and this side pressure plus rho the pressure of this coulomb, pressure of this coulomb equivalent to h is rho f gh. Now if you want to have the gauge pressure that is p minus pa it is going to be p minus p a is going to be gh rho m minus rho f.

Often when the when rho m is much greater than rho f and often it is neglected also, and this is how we get the gauge pressure and absoluter pressure in case of U tube manometer. The U tube can also be used for differential pressure measurements as we have seen in the case of venturimeter.

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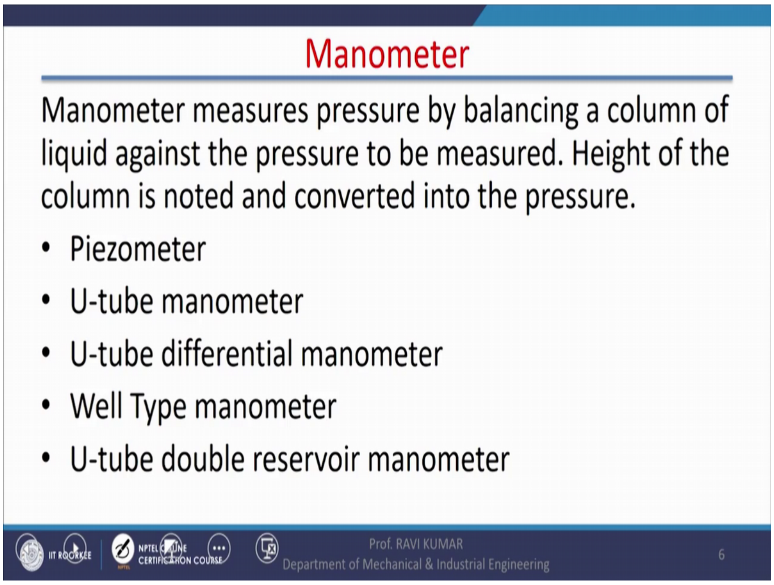

Now, differential manometer right. So, in differential manometer.

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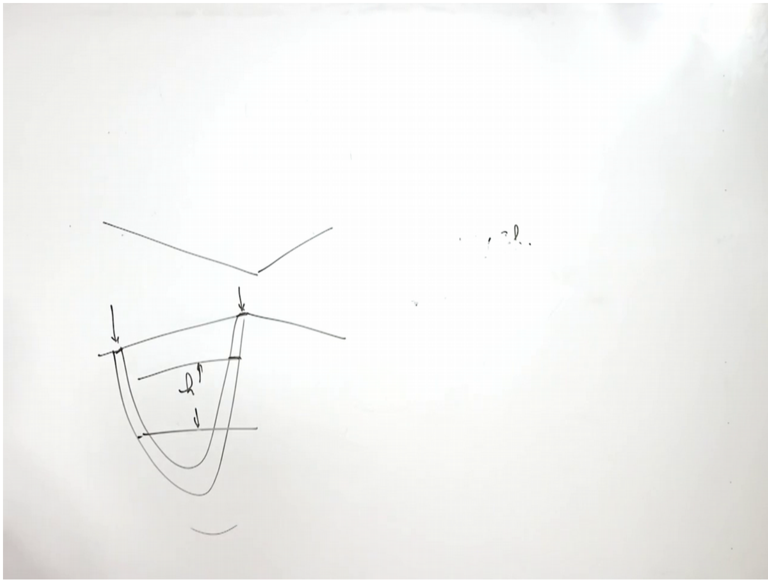

So, let us take case of a venturimeter there is a U tube manometer and both sides are not a any of the sides is not exposed to the atmosphere. So, pressure is exerted here and pressure is also exerted here right and then the difference in the coulomb h will show the magnitude if pressure difference, and these type of calculations we have already done. In differential pressure manometer none of the side is atmosphere exposed to the atmosphere in fact, both sides are pressurized and difference in the coulomb the pressure the difference level difference in the coulomb speaks about the differential pressure, and this can be easily calculated by using the Bernoulli's equation. Now there is another type of manometer which is known as well type of manometer.

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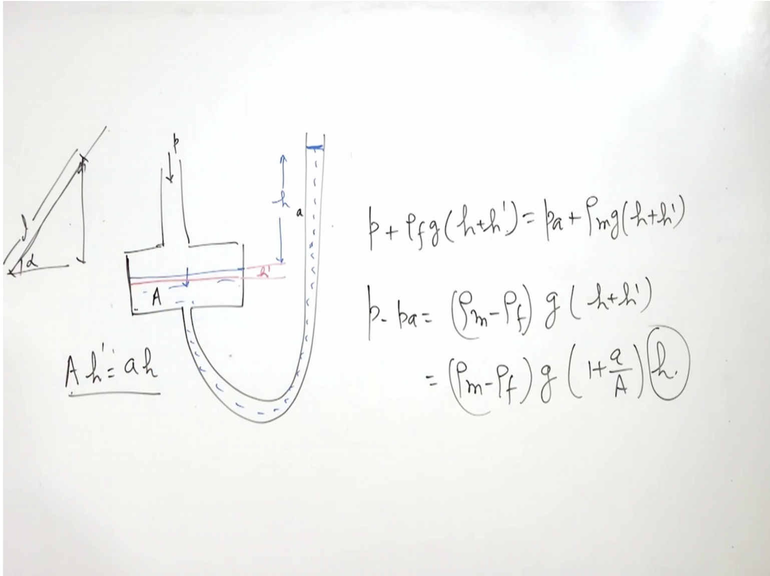

In well type of manometer there is a well which is having a very high volume, and this side is connected to certain pressure or exerted by certain pressure. And this bottom of the well through U tube is connected to a transparent tube which has negligible cross section or very low cross section as we compare this well. Now this well and the U tube are filled with some fluid like say mercury and because, but is pressurized some coulomb has been developed this is known as h, because the volume of this fluid is not infinite. So, in this process the level of this mercury level or the fluid level in this will also go down and that is let us say there are new acquired level is this, and this is h dash.

Now we will do the pressure balance, now for the purpose of pressure balance now the pressure difference is this much not h plus, but it is h plus h dash right. So, p plus rho fg h plus h dash this is the equivalent coulomb here is equal to atmospheric pressure plus rho m g h plus h dash. Now will not take here h we will take h plus h dash. And now again p minus pa is going to be rho m minus rho f into g multiplied by h plus h dash. Again here if we take the volume then if cross section of area of this is A and the cross section of area of this a small a. Then A multiplied by h dash equal to a multiplied by h. Now here will replace the h dash by this and will get rho m minus rho f g 1 plus a by A h.

Now, if A is much larger than a then we will neglect this and we will get rho m minus rho f g h. Now this is 1 case if sometimes this height is not sufficient suppose height is 1 millimeter, 2 millimeter in that case, in any of the manometer and arc is inclined right and we had certain angle alpha right and this length l alpha may be 10 degree or 20 degree. So, that we get sufficient length of coulomb this increases the accuracy of the measurement, and then will take l sign alpha this is the actual head. So, this head h also can be replaced by l s alpha if this r is inclined right.

So, this is the well type of ah manometer and U tube double reservoir manometer. We can have reservoir of this side also double reservoir manometer, these type of manometer are also there right. So, we can have several type of arrangements, but the fact remains we have to use the make use of Bernoulli's equation right. And if there is a difference in elevation sometimes there is a difference in elevation also for example, the entry of one type ids this and entry of other type is this right and then they are connected by the differential manometer right.

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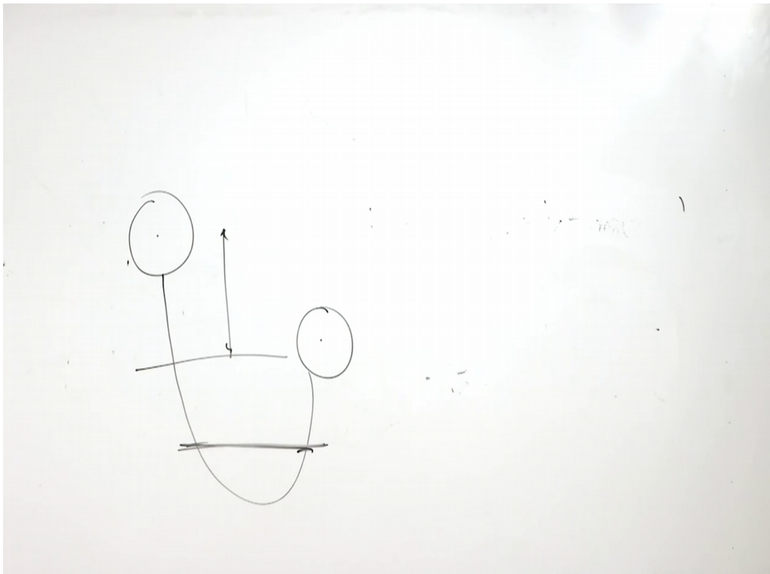

So, for every case now here h will also this, this also will add to the head. So, ultimately we have to make the pressure balance on both the legs of the manometer, when pressure is same and then we can measure the pressure above this side and pressure above this side and we have to balance that pressure.

So, this is the basic methodology for finding out the pressure or pressure difference using the manometers. Now manometers are in inexpensive and accuracy is also good, but they have poor response or they are not used for the dynamic response also system they are they are very good for the static measurement they are suitable for the low pressure for high pressure we can also suppose I have to measure absolute one third 1 work is pressured with help of the manometer, then we will have to go for 10.3 meter height of tube, which is difficult to handle it is fragile also it is a blast tube.

So, fluids has to be compatible. Suppose fluids they have to react with each other and the pressure gauge will not work. So, both the fluids that is the working fluids and the fluid of which the pressure is being measured, they have to be compatible and the scope of error in the this U tube manometer is first is capillary effect, certain height we get through capillary effect also and another is reading in manometer.

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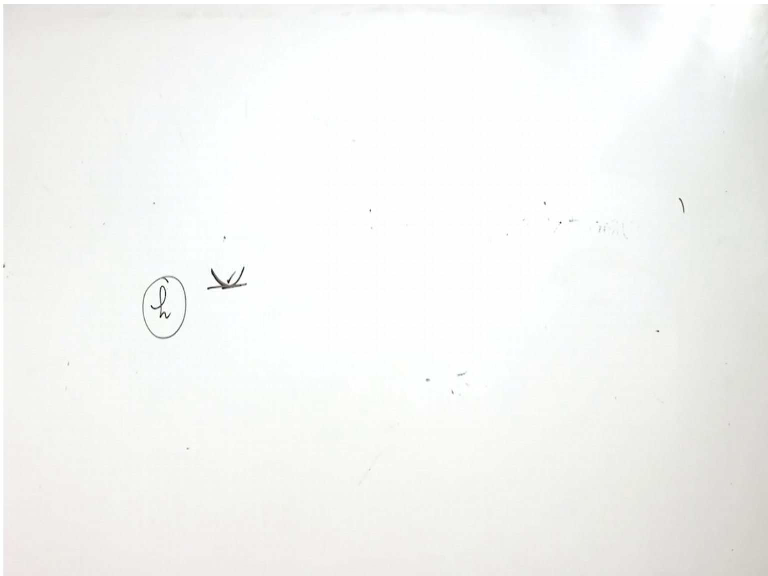

One should correctly read the (Refer Time: 21:27) of the height of the coulomb, otherwise there are chances of error. And lastly the gravity and temperature they have also they have also bearing on the measurement of measurement by the manometer.

So, they have to be taken into the account. Now after the manometers the several gauges.

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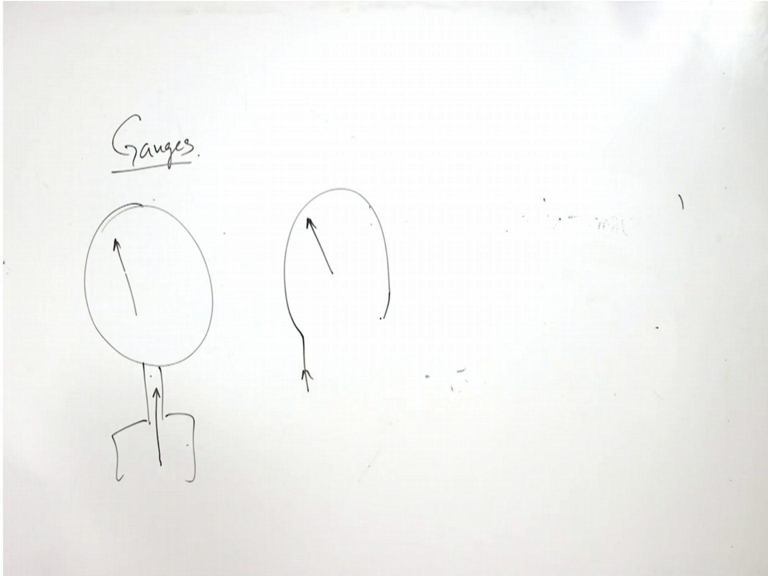

And normally for high pressures we go for the pressure gauges. And pressure gauges there is a dial and there is an indicator and this side is connected to any vessel or pressurized media and when the pressurized is exerted on the dial gauge, there is the deflection in the radial gear at the output from the pressure degree. But inside the pressure gauge normally there is a broaden tube, which gets expanded I have working the I have already explained the working of broaden tube in a pressure gauge, which causes a deflection of the needle or it may be diaphragm type of gauge.

Suppose there is a pressure transducer in a pressure transducer if you see basically if you look at there is a small cylinder maybe of the length of say 2 inches and diameter of 1 half inch right.

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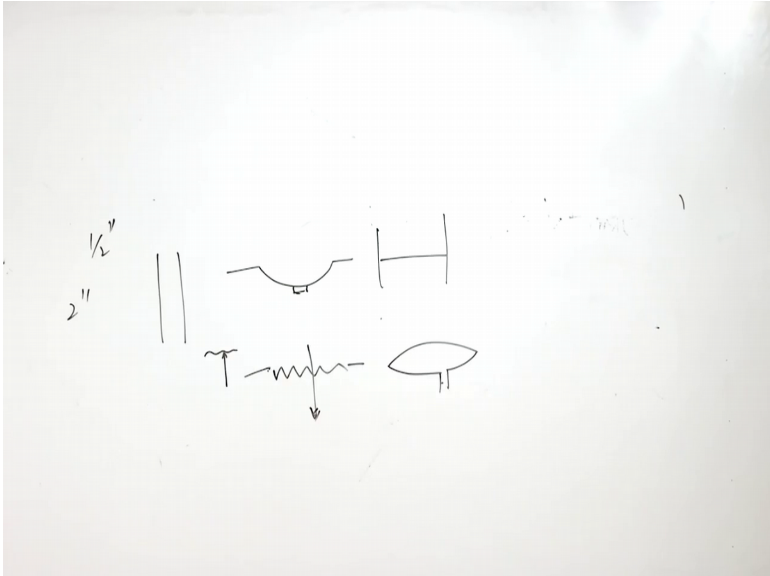

So, it is a cylinder, but inside it there is a diaphragm and on the diaphragm when the pressure is exerted, deflection of diaphragm takes place. And when we are able to measure the deflection in the diagram diaphragm we can convert this deflection into the electrical pulse, this diaphragm can be of dish type this is dish type diaphragm. It can be a flat type of diaphragm, this is normally used for small size of pressure gauges, it can be a corrugated diaphragms and it can be a capsule shape of diaphragm.

It depends the application in the size of the pressure gauges, the corrugated specially corrugated diaphragm is used to improve the performance of strain gauges, it is used for large size of strain gauges and this corrugated this diaphragm also increase the linearity when there is a there is a deflection, the linearity between the low applied and the deflection and it causes less stress it is obvious.

It causes la less stress, but dynamic response of the corrugated diaphragm is not that good ok. So, it is not so many used where static signals are there this corroted corrugated type of diaphragms for diaphragm and broaden tubes there are two important primary sensing elements, and on the diaphragm you can put for measuring the deflection you can use several type of you can put a strain gauge on the diaphragm right the strains will be developed or you can put a piezoelectric transducers on the diaphragm that will also convert the four signal in to the electrical signals. So, but they have also have limitations, the limitations is first of all diaphragm of the strain gauges has no response I have already stated they also show a certain order of stresses and output is feeble out output is weak.

So, amplification of the output is also required in such type of diaphragm type of strain gauges, they are (Refer Time: 25:17) type to the shock and the vibrations. So, care has to be taken while installing these strain gauges, that the place is free from ah shocks and the vibrations. Material for these strain gauges diaphragms need normally nickel, chromium or iron and elastic limit of the foil is 560 mega Pascal.

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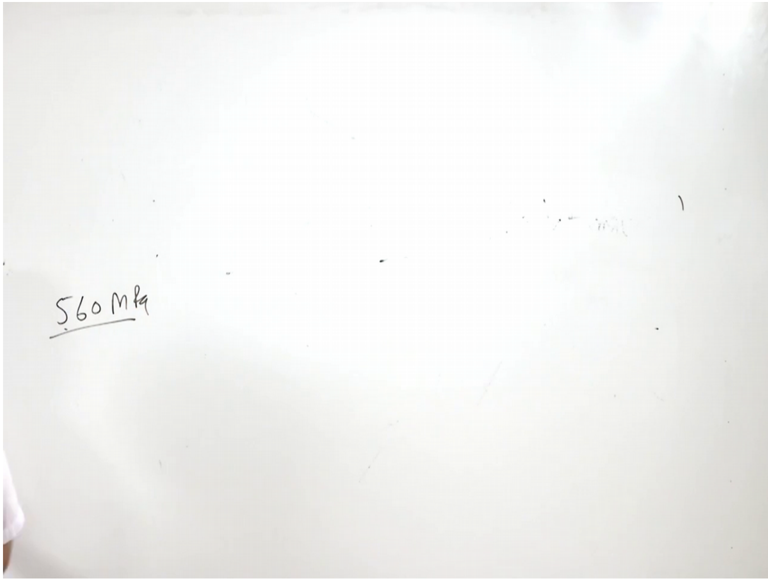

Approximately let us say 500 mega Pascal 560 or safely we can take 500 mega Pascal. For low pressure measurement, for low pressure measurement McLeod type of pressure gauge is used it is very popular.

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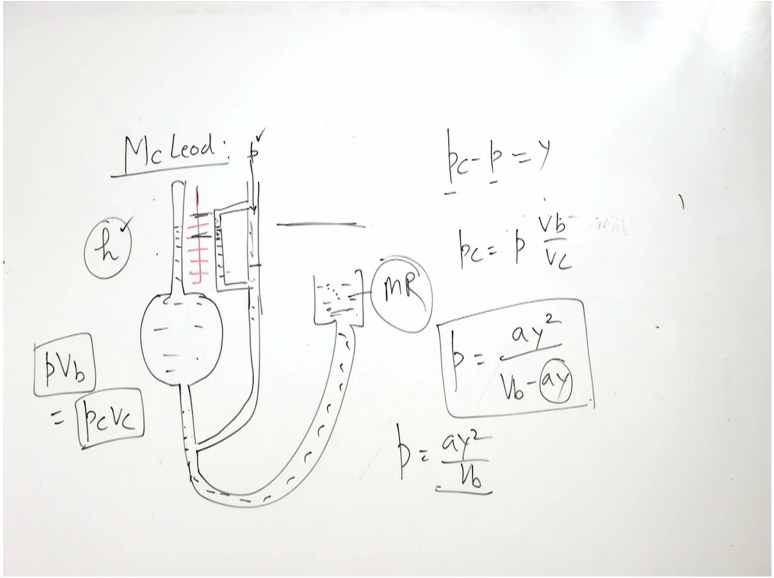

Now in McLeod pressure gauge, there is a bulb right and bulb has a tube and tube has two bifurcations. One is going this side, another is going to this side and there is a vessel and vessel with filled some let say mercury if it some fluid like mercury. So, mercury is filled here, mercury is also filled here and this side. Now this has a coulomb this side has a coulomb right and this side is also having coulomb, this side is also having a coulomb and coulomb has a bifurcation also arrangement is something like this and.

Here there is a temperature scale some scale is provided here right. Now this is also open. Now this moveable reservoir is lowered. When the moveable reservoir is lowered the pressure of the mercury or fluid starts falling let us say right. And the fluid of which the pressure has to be measured is start entering this tube and will keep on lowering this moveable reservoir moveable reservoir. When it goes below this mercury goes below this point, the entire full will fluid will enter here right when fluid enters here will start raising this moveable reservoir and the fluid will start getting the compressed and it will come somewhere here pressure will increase it is isothermal compress compressor p 1 v 1 is equal to p 2 v 2 right This will go hold good here.

So, when it is compressed then it is confined to this space. This volume is measured because we have a devoid scale here this volume can be easily measured, cross section area and the volumes are known to us. So, and we have pressure here also the fluid is filled in this arm also, and due to pressure here there is a differential in pressure which is denoted by h right. Am repeating the fluid which is coming here enters in this in the in this ball and we lift the moveable reservoir this fluid starts getting compressed pressure keeps on increasing and when again this point is regained. I mean same level is regained by this moveable reservoir some pressure difference because earlier there was no pressure, now there is a fluid in it. So, pressure will be there. So, there will be there is going to be the difference in the levels and this is shown by h, h is the height of the coulomb here.

So, t into volume of the bulb volume of the bulb here its quite large is equal to pc vc volume of the capillary. Pressure into volume of the bulb is equal to pressure in the volume of the capillary. So, first initial volume and the last volume right. So, we have equated them and pressure in the capillary minus p is equal to y and t is this pressure. So final pressure minus initial pressure is y, now p why am writing y why am not writing yh we are not writing yh because it is expires in terms of coulomb of mercury.

So, p is also expressed in coulomb of mercury, in this got Pascal or kilo Pascal. So, and pc is also is equal to p V b by V c now using these two equations, we can find the value of p, p is equal to ay square divided by V b minus ay. If you manipulate these two equations this is going to be the final expression right or if you want to neglect ay because ay if you compare the volume of this bulb it is much larger than the volume of the capillary, then p is equal to a y square by V b.

Now, to have a clear understanding of the pressure measurement by McLeod gauge, let us try to solve this numerical which states that a McLeod gauge has v b is equal to 100 meter. So, volume of the bulb is volume of the bulb 100 centimeter cube volume of the bulb 100 centimeter cube.

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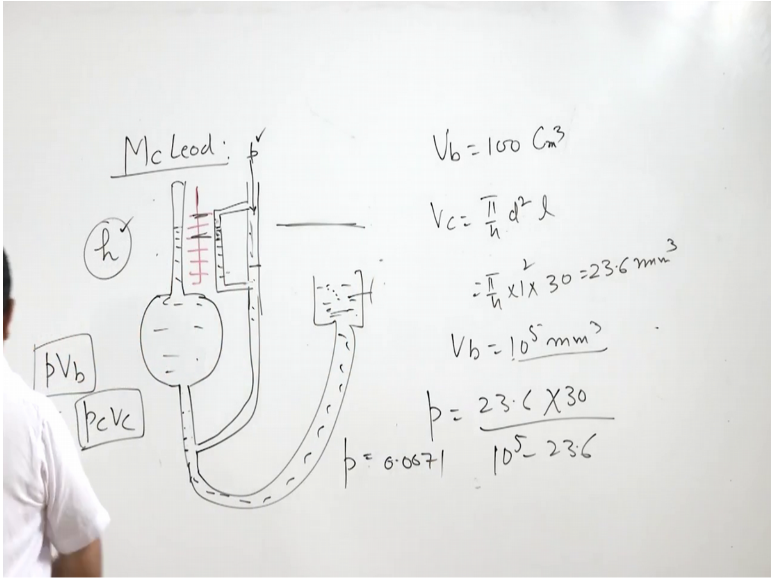

So, if a reading of 30 mm is here volume of the bulb is 100 centimeter cube. So, volume of the capillary is going to be pi by 4 d square l is equal to pi by 4 into 1 square into 30 into 23.6 mm cube. Volume of the bulb is 10 to the power 5 mm cube right and then pressure is 23.6 volume of the capillary is multiplied by 30 thirty it is the height of the coulomb it is 30 mm reading of 30 mm. So, height of the coulomb is 30 divided by vb it is 10 to the power 5 minus 23.6 volume of the capillary if we solve this will be getting the value of p as 0.0071 Torr.

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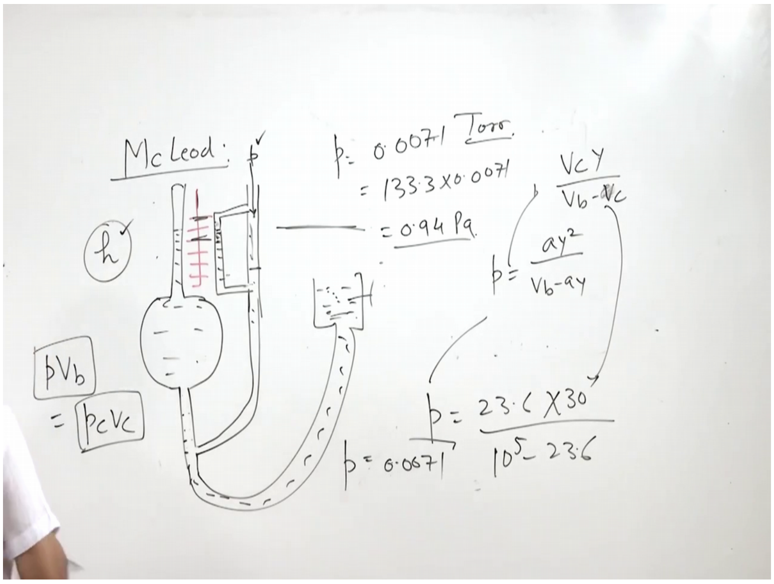

This p is equal to ay square divided by V b minus ay or we can write aV capillary a sorry ay is the volume of the capillary this ay is volume of the capillary and y minus V b minus ay is also volume of the capillary, it can be written like this also.

So, we have used this here to find the value of p. And p is how much? 0.0071 torque. If you multiply this (Refer Time: 33:59) this is torque if we multiply this by 133.3. We will get pressure in kilo Pascal and that pressure is 0 point sorry in Pascal's. So, the pressure is 0.94 Pascal. Now if we neglect this right. So, we are getting two pressures one is considering the capillary volume another is neglecting the capillary volume. If we are considering the capillary volume, then we are getting 0.9464.

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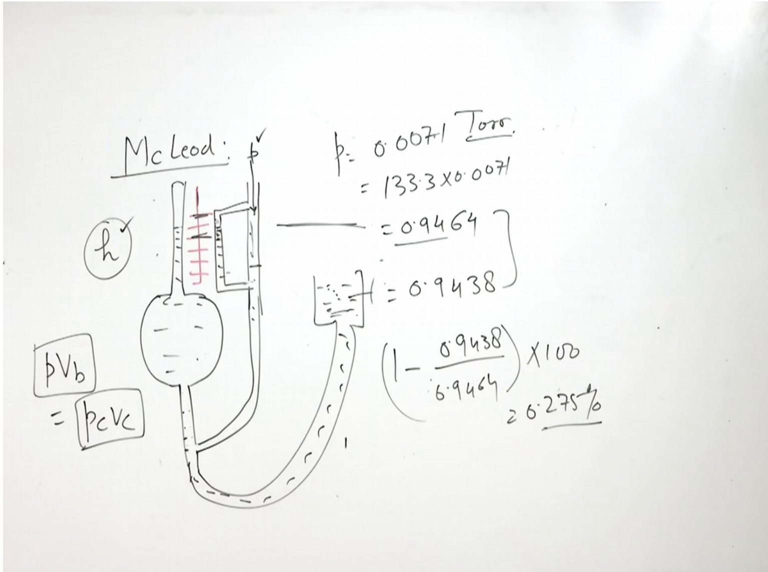

And when we are neglecting the capillary volume, the pressure is 0.9438. If you want to find the error in the measurement, the error in the measurement is going to be 1 minus 0.9438 divided by 0.9464 multiplied by 100 and this will give 0.275 percent of error. So, even if we neglect the volume of the capillary, the contribution of error is not very significant. That is all for today.

Thank you very much. In the next class we will start with the force measurements and the torque measurement.