Chemical Process Instrumentation
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Lecture – 22
Pressure Measurement: Moderate and High Pressure Measuring Instruments (Contd.)

Welcome to lecture 22, we have started our discussion on pressure measurements and we are talking about measurements of moderate pressures and high pressures. So, in the previous lecture we have talked about various types of manometers.

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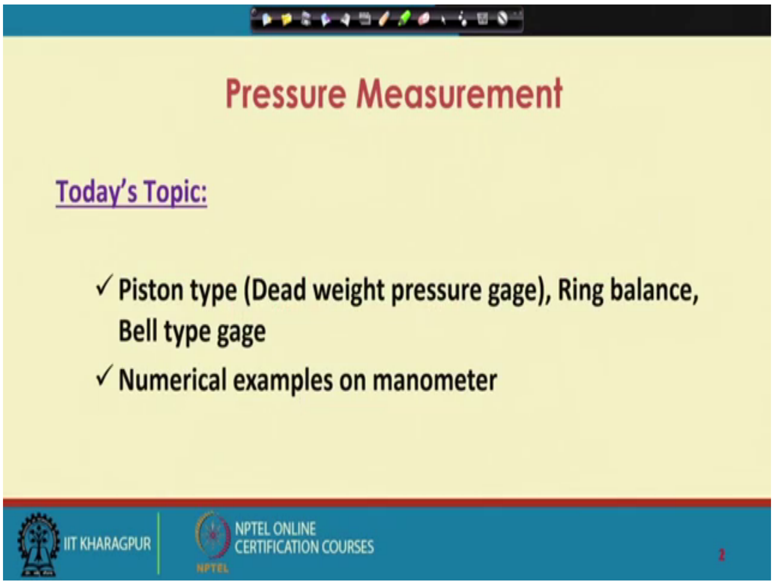

In this lecture, we will talk about piston type or dead weight pressure gage, ring balance pressure gage and bell type pressure gage; then we will take few numerical examples on manometers.

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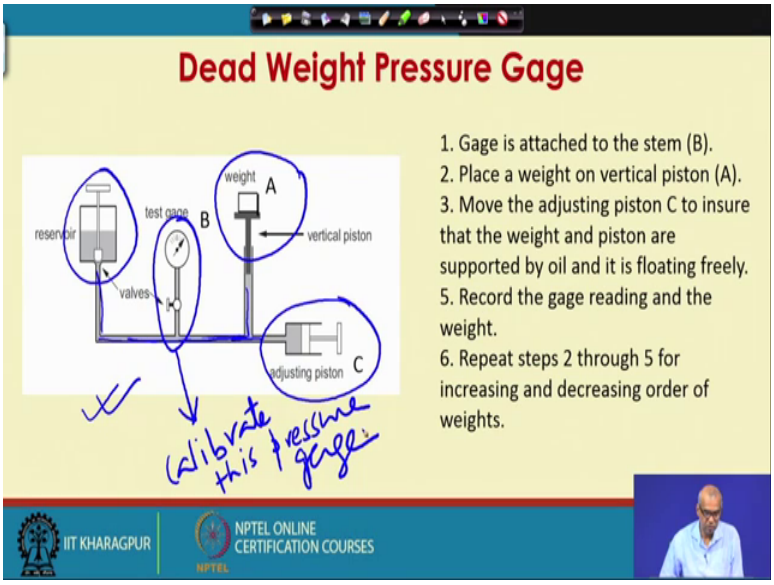

So, let us first talk about dead weight pressure gage; look at this schematic for a dead weight pressure gage. It consists of a vertical piston, then there is an adjusting piston and you have a reservoir. So, all are connected and then you attach a pressure gage here. So, this dead weight pressure gage or dead weight tester can be used to calibrate a pressure gage.

So, the steps for calibration of the pressure gage using dead weight pressure gage are as follows. Gage is attached to stem B, now we place a suitable weight on the vertical piston. So, you select a suitable weight and place it on the vertical piston A; move the adjusting piston C so that weight and piston are supported by oil and it is floating freely.

So, the piston must be floating freely please note that the entire tubes are full with or filled completely filled with oil. Now, when I place weight on this piston; the piston should be freely floating, it must not come down and support itself by this platform or the piston; so, it should be freely floating. At this stage, you record the gage reading and the weight; so, look at the gage reading and the weight.

So, now you select another weight and place it on the vertical piston and see the gage reading. So, repeat this steps; in the increasing order of weights and then you can also have observations on decreasing order of weights. So, these are your known weights; so these are standards or primary standards.

So, you know the pressure that is being applied; so, from the gage reading you can now calibrate this gage by comparing its varying against the known standard.

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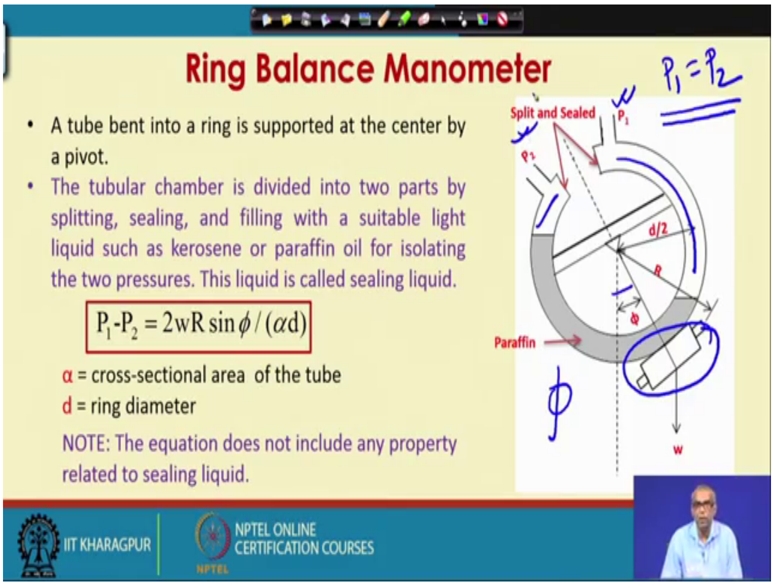

Let us now talk about ring balance manometer; note that the dead weight pressure gage as well as the ring balance manometer are the instruments where I am measuring pressure by balancing in against known force. A ring balance manometer is used to measure differential pressure; this is a schematic of a ring balance manometer. It consists of a tube with circular cross section, the tube may be made of plastics, the made of may be made of aluminium, metal and so on and so forth.

So, a tube is bent into a ring and is supported at the centre by a pivot; the tubular chamber is divided into two parts by splitting, sealing and then filling with a suitable light liquid such as kerosene or paraffin oil for isolating the two pressures. This liquid is known as sealing liquid, so, you first take a tube maybe of made of plastics or maybe made of say aluminium; bend it into a ring; this is supported at the centre by a pivot.

Now let us cut the tube and two ends that are now created are sealed and then inside, I take a sealing liquid; then I create two chambers one chambered is this another chamber is this.

So, a ring which has a partition here; inside that I take sealing liquid, so I basically create one chamber here, I create another chamber here. The liquid that I take inside is known as sealing liquid and common sealing liquids are kerosene and paraffin oil. One can also take glycerine; these ends are connected to the pressure source which I am going to measure.

So, I am going to measure differential pressures; so I am connecting this to two different pressure sources P 1 and P 2. Now when P 1 equal to P 2; that means, the two ends are connected to the same pressure source; the tube will not experience any torque, that tube will show no movement. But if these two limbs are connected to two different pressure sources or these two chambers are connected to two different pressure sources.

Then the ring balance manometer will experience a torque which will try to rotate the ring. And then there is a weight attached to the ring which will try to arrest that rotation. So, there will be a balance between these two opposing forces and when balance is obtained, the rotation of the ring or the angular rotation of the ring which is measured by an angle phi becomes the measure of the differential pressure.

So, when P 1 is equal to P 2; the angular rotation will be 0, because the ring will show no rotation. But when P 1 is not equal to P 2; that means, the ring balance is connected to two different pressure sources there will be a net torque which will try to rotate the ring. Let these rotation be measured by angle phi; so, this phi is a measure of the differential pressure P 2 minus P 1, you can derive the equation.

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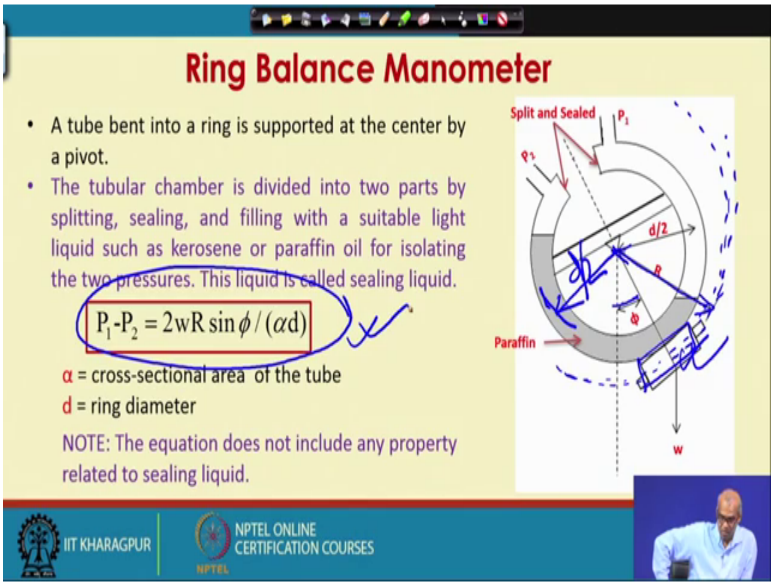

Which is P 1 minus P 2 equal to 2 w R sin phi to divided by alpha into d, where alpha is the cross sectional area of the tube; w is the weight attached to the ring R is the diameter. But, which diameter? Please look at here; this diameter we have attached the weight and then consider a circle like this. So, that radius is R; phi is the angle by which the tube has or the ring as rotated and d is the ring diameter; so this is the d by 2.

So, this equation can be written by analysing the torque; please look at this equation of carefully. This equation does not include any term that is related to the property of the sealing liquid. So, what it means is the sealing liquid merely works to create two chambers for pressure applications. It does not play any role in the calibration of the instrument because the property of sealing liquid does not appear in the working equation.

So, if you change the sealing liquid; the working equation is no way going to be affected, the sealing liquid only creates two different chambers for applications of pressure.

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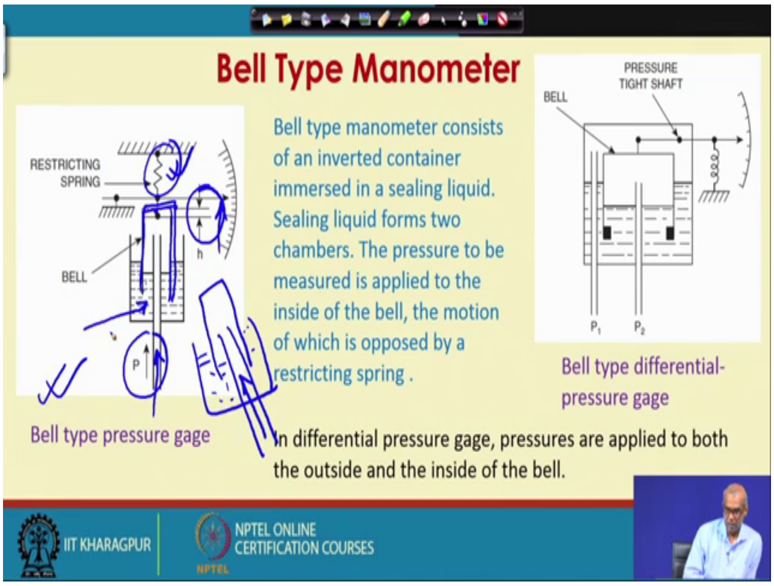

Now, let us talk about bell type manometer; so, we talked about dead weight tester or dead weight pressure gage also known as piston pressure gage. We talked about ring balance manometer and now we are going to talk about bell type manometer. All these three instruments work on the principle that you balance the pressure against a known force.

Bell type manometer consists of an inverted container which is immersed in a sealing liquid. So, this is the bell; first let us consider this schematic, this is the bell type pressure gauge. So, it consists of a inverted bell; so it is nothing, but a container which is inverted and it is inverted and immersed in a pool of sealing dinner liquid.

So, this is sealing liquid; now the bell is spring restricted. Now look at here; you had a reservoir of sealing liquid and then you have put an inverted bell. And then you are applying pressure inside the bell; so, you have created chambers like this. So, when you apply pressure inside, it will try to push the bell up of course, that will be restricted by the spring. And the displacement shown by the bell is noted as h; this displacement of the bell is a measure of this pressure.

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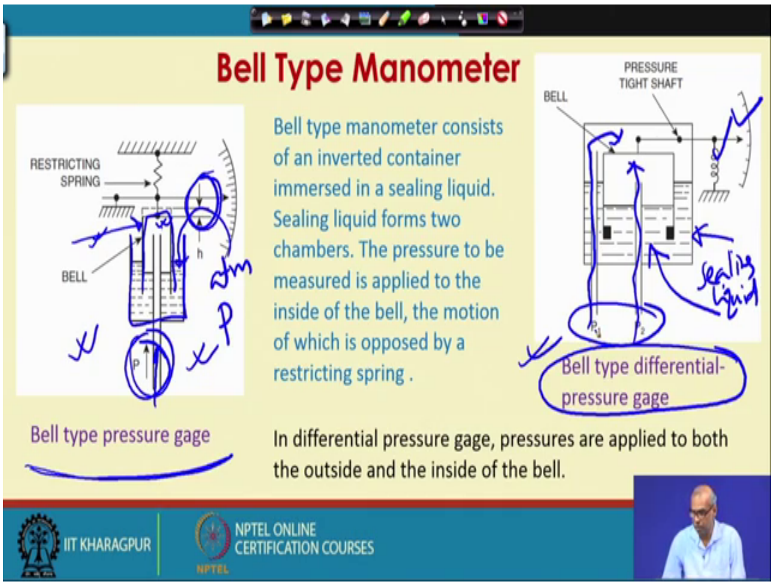

Note that when you invert this bell in this reservoir, you create a chamber for application of pressures. So, inside that you apply the pressure which you are going to measure; there is application of say atmospheric pressure here. And these atmospheric pressure and these pressures are separated by the sealing liquid. So, the net displacement of the bell which is measured by h is basically a result of application of this pressure and the atmospheric pressure, so this h will be a measure of the gauge pressure.

So, bell type manometer consists of an inverted container immersed in a sealing liquid. Sealing liquid forms two chambers the pressure to be measured is applied to the inside of the bell, the motion of which is opposed by restricting spring. And the motion of the bell is the measure of the pressure that you are applying inside of the bell.

Now, the bell type manometers can also be used for measurement of differential pressures. Here the bell type pressure gage we used to measure gage pressure, now let us look at this schematic which can measure differential pressure; we called it bell type differential pressure gauge. Now, if you was to measure differential pressure you have to apply two different pressure sources.

In this case the pressure that I wanted to measure was applied inside the bell; and from outside, the atmospheric pressure work. Let us say on the outer surface of the bell or on this liquid, it was atmospheric pressure that was working.

So, the movement of the bell here was a result of this application of this pressure as well as the atmosphere pressure; that is working from the outside of the bell. So, in case of differential pressure gauge; we have to connect the pressure gauge to two different pressure sources. So, I will apply one pressure inside the bell and I will apply another bell; another pressure from outside of the bell, so that is what we do. So, what we have to do is; I have to make use of a sealed chamber, here the chamber was open but here I have to use a sealed chamber.

So, the bell type differential pressure gauge will consists of an inverted container immersed in a sealing liquid and the sealing liquid is taken in a sealed chamber. Now as usual I apply one pressure inside the bell and the other pressure, you see is being applied from outside the bell. Now these two pressures are separated by the sealing liquids; again due to differences in this pressures P 1 and P 2, the bell will show a moment which can be used to move this pointer against this scale. So, the movement of the pointer against the scale can be used to measure the differential pressure P 1 minus P 2.

So, bell type manometer can be used both to measure differential pressure as well as gauge pressure.

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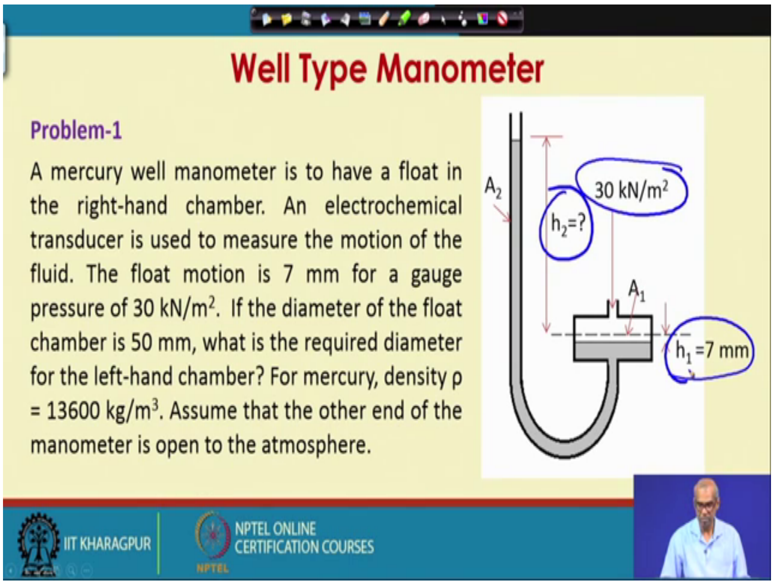

Now, let us take a problem on well type manometer. A mercury well manometer is to have a float in the right hand chamber and electromechanical transducer is used to measure the motion of the fluid. The float motion is 7 millimetre for a gauge pressure of 30 kilo Newton per metre square, if the diameter of the float chamber is 50 millimetre what is the required diameter for the left hand chamber? For mercury density is equal to 13600 kg per metre cube. Assume that the other end of the manometer is open to the atmosphere.

So, basically consider a well type manometer; we want to have a float in the right hand side chamber. So, here I want to have a float, a electromechanical transducer is used to measure the motion of the fluid. The float motion is 7 millimetre for a gauge pressure of 30 kilo Newton per metre square. If the diameter of the float chamber is 50 millimetre what is the required diameter for the chamber? So, what should be the diameter of the chamber? Density of the mercury is given.

So, first let us try to find out what is h 2? Given; for 30 kilo Newton per metre square, pressure this level of mercury in the well goes down by 7 millimetre.

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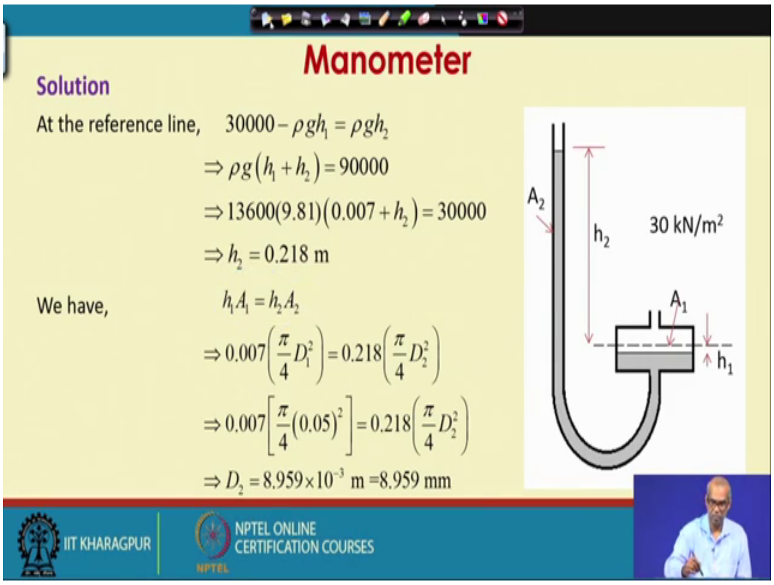

So, when you apply 30 kilo Newton per metre square pressure; we have h 1 equal to 7 millimetre. So, I can write 30 kilo Newton per metre square; which is 30000 equal to rho g h 1 plus rho g h 2. So, if we solve this is 30000; so if you solve this equation you will get h 2 equal to 0.21 metre. So, once I have h 2; I can make use of the volume balance h 1 equal to h 2 to find out the area and to after finding out area I can find out the diameter. So, you make a volume balance h 1 A 1 equal to h 2; A 2. So, you can write this equation the area can be taken as pi D square by 4. So, after putting all values we can calculate the diameter.

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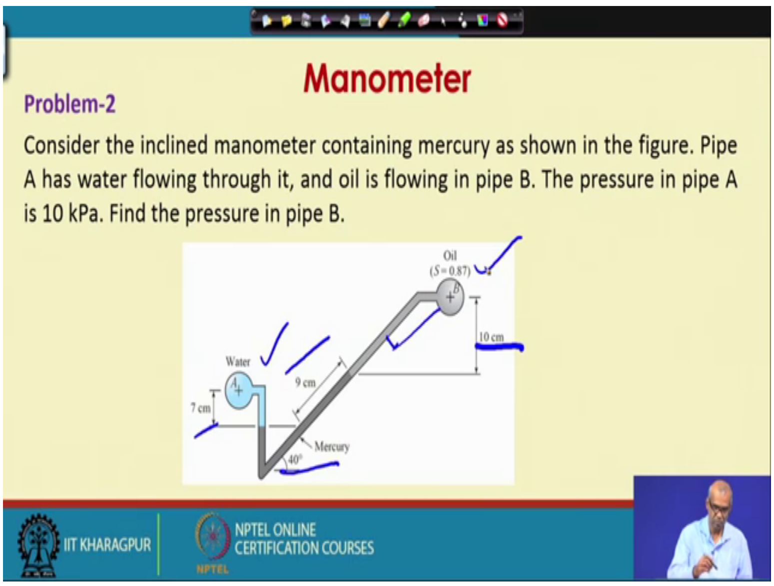

Let us take another example on manometer consider the inclined manometer containing mercury as shown in the figure. Pipe A has water flowing through it and oil is flowing in pipe B, the pressure in pipe A is 10 kilo pascals. Find the pressure in pipe B; also consider the dimensions that are shown the numbers that are put in the figure.

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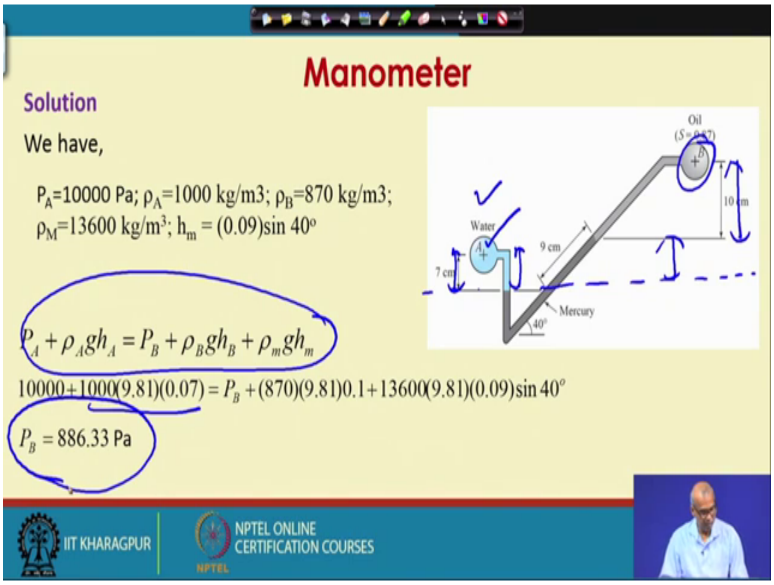

What is given is P A is 10000 pascals density is 1000 kg per metre cube, it is density of water. Density of oil is 870 kg per metre cube, density of mercury is 13600 kg per metre cube and h m is 9 centimetre converted to 0.09 sin 40 degree.

Now, let us put all these numbers together and write down this balance. So, basically we are writing a balance along this line; so I can write P A plus pressure due to this, which is density rho A times g, times 7 centimetre which is 0.07 metre is equal to P B plus rho g h term corresponding to this and also rho g h term corresponding to this. Once you do the calculation, you give P B equal to 886.33 Pascal.

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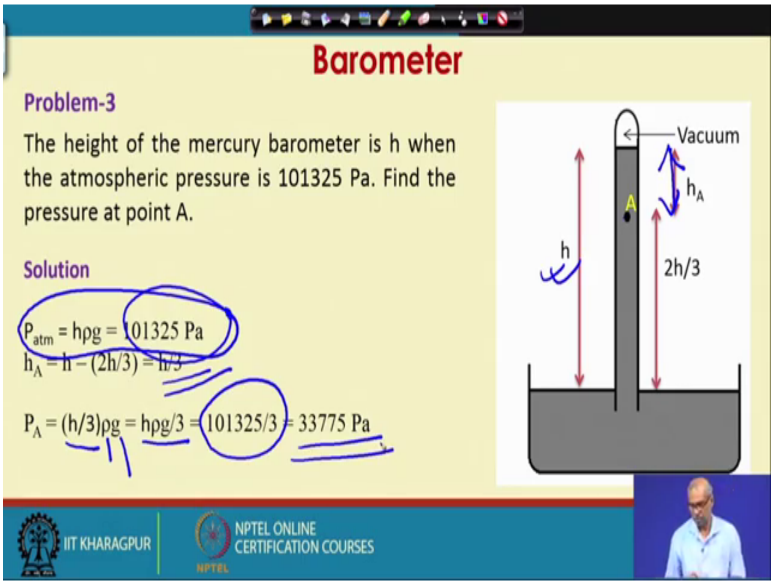

Finally, let us take another very small example on barometer. The height of the mercury barometer is h; when the atmospheric pressure is 101325 Pascal. So, height of the mercury barometer is a h when the atmospheric pressure is 101325 Pascal. Let us try to calculate the pressure at point A. Is given that this distance is 2 h by 3 and this is h A.

Atmospheric pressure is equal to rho g h is given as 101325 Pascal; h A is h minus 2 h by 3 is h by 3. So, pressure at P A is due to this column of mercury, so h A is h by 3. So, h by 3 into density of mercury into acceleration due to gravity, which is rho g h by 3; rho g h is this term; so one third of that is equal to 33775 Pascal. So, will stop our lecture 22 here.