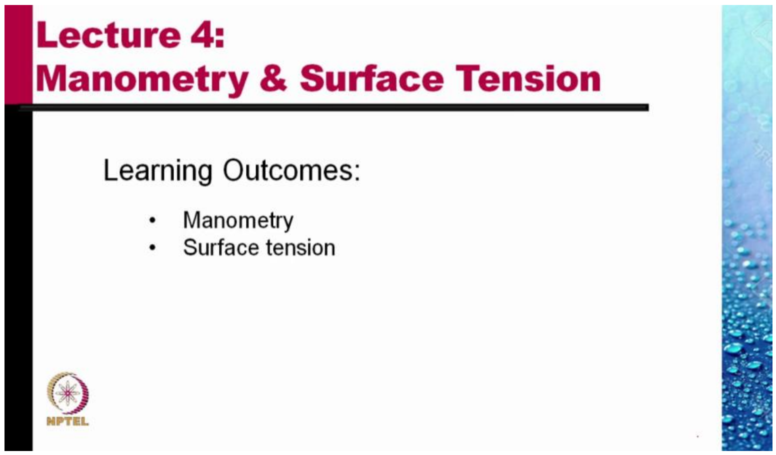
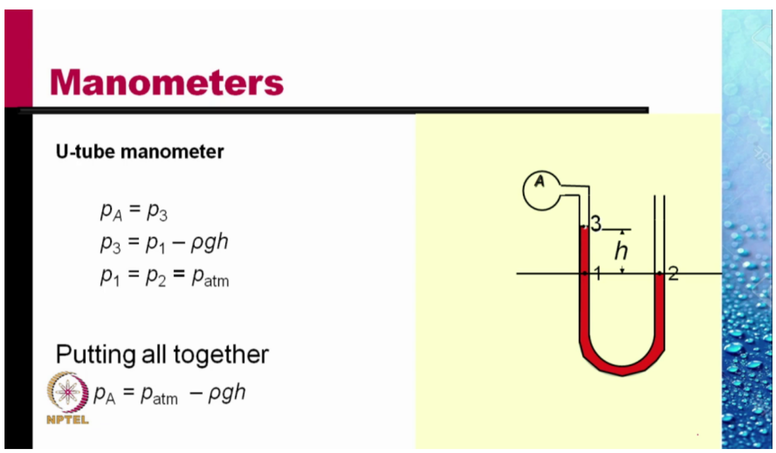
Fluid Mechanics and its Applications
Professor Vijay Gupta
Sharda University
Indian Institute of Technology, Delhi
Lecture: 4
Fluid Mechanics and Its Applications

Welcome back. In this fourth lecture, we will cover Manometry and Surface Tension.

(Refer Slide Time: 00:27)

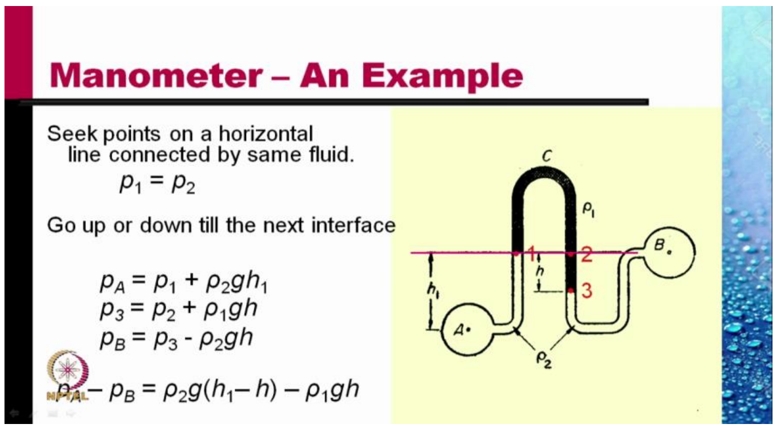




Manometry is connected with measuring the pressures. One of the simplest manometers is a U-tube manometer. In this case in the picture shown with a bulb A which contains a gas and then a liquid column shown in red in a tube. The difference in the levels in the two limbs is h. The pressure at A can be measured by using the principle that the fluids have the same pressure at the same horizontal level if the fluids are connected.

So, in this case, point 1 and point 2 will have the same pressure. Since, the density of the gas is very small, we can say p_A is like p_3, and p_3 is $p_1 - \rho gh$, because from p_1 we are going up a distance h. So, it is $p_1 - g\rho h$, and p_1 is equal to p_2 is equal to atmosphere. Putting it all together p_A is equal to $p_{atmoshere} - \rho gh$. The pressure of the gas inside the bulb is lower than the atmospheric pressure by an amount ρgh, where ρ is the density of the manometric fluid in the tubes.

(Refer Slide Time: 02:11)

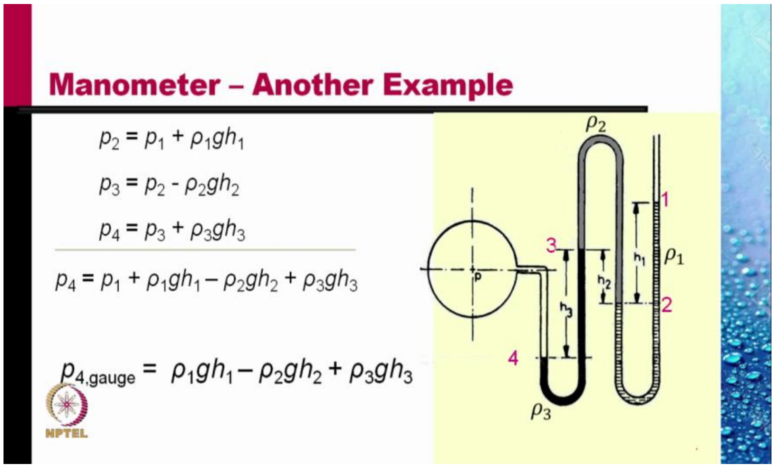


Consider two bulbs A and B. the bulbs A and B are filled with a liquid of density ρ_2 These bulbs are connected with an inverted U-tube. The black fluid has a density ρ_1. The difference in the levels of the fluids is h as shown clearly. We can calculate the pressure difference $p_A - p_B$ through a process similar to what we did last time.

We seek points on the horizontal level connected by the same fluid. Points 1 and 2 are two points at the same level connected by the same fluid. So, the pressure at 1 must be equal to pressure at 2. We will exploit this fact to calculate the pressure difference $p_A - p_B$. We go up or down from points 1 and 2 till the next interface. In this case, p_A is clearly $p_1 - g\rho_2 h_1$, since, the uncolored portion of the tube is filled with a fluid or density ρ_2.

So, pressure at 1 is higher than pressure 1 by a liquid column of height h and of density ρ_2. Similarly, p_3 which is below p_2 is equal to $p_2 + \rho_1 gh$, where h is the height of column 3 to 2, and ρ_1 is the density of the fluid there. Similarly, p_B is equal to $p_3 - \rho_2 gh$. Since, B is higher than point 3, so, the pressure is lower. Putting in all together, that is summing these three equations, we get p$p_A - p_B$ is equal to $\rho_2 g(h_1 - h) = \rho_1 gh$. If we know the height h and h_1 and the densities ρ_1 and ρ_2, we can calculate the pressure difference $p_A - p_B$.

(Refer Slide Time: 04:59)



We do another example: a little more complicated manometer here: We have a bulb with a pressure p of a gas, and the manometer has three fluids of density ρ_1, ρ_2 and ρ_3, as shown. We use the standard method of calculation: that we seek points at the same level connected by the same fluid and equate the pressures in the two different limbs. And then we move up and down within a fluid to the next interface. Let us mark points 1, 2, 3 and 4. These are the levels at which the fluid changes. Clearly, p_2 the pressure at point 2 is greater than the pressure at point 1 in the right most limb, and is given as $p_2 = p_1 + \rho_1 gh_1$. In the second limb from the right, the pressure at level 2 is the same as p_2. And so, the pressure in this middle limb at the level of point 3 would be the same as pressure at 3. And the pressure at 3 is lower than pressure at 2 by an amount $\rho_2 gh_2$.

So, p_3 can be written as $p_2 - \rho_2 gh_2$. Now point 3 is above point 4. So, pressure at point 4 is $p_3 + \rho_3 gh_3$. Putting it all together, we get p_4 is equal to $p_1 + \rho_1 gh_1 - \rho_2 gh_2 + \rho_3 gh_3$. Since p_1 is the atmospheric pressure, so the gauge pressure at point 4, $p_{4,gauge}$ is given simply by $\rho_1 gh_1 - \rho_2 gh_2 + \rho_3 gh_3$.

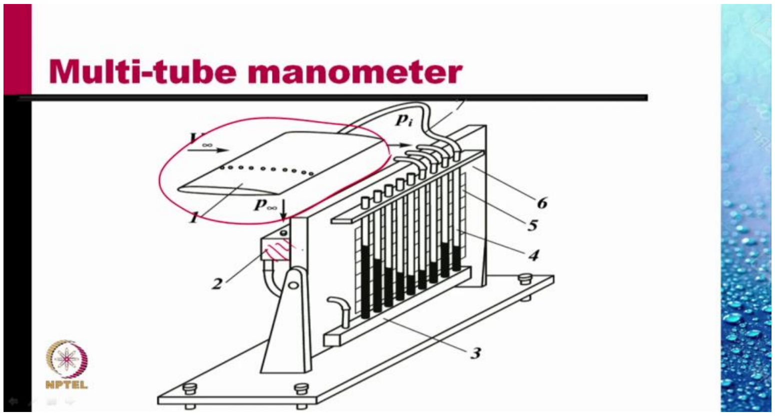
(Refer Slide Time: 07:49)

In all these applications we, typically, will have to make two measurements of levels. and then the pressure relates to the difference between two levels. Sometimes, we use a limb with a much larger cross section area, and the resulting reservoir manometer is as shown. There is a fluid in a very large cross-sectional area reservoir to which a pressure *p* is applied.

Because of this pressure *p*, the fluid contained within the reservoir rises up a thin capillary. Since, the diameter of the capillary is very small, as the fluid level changes in the tube the level within the reservoir does not vary significantly. And we can assume that this is at a constant level. So, that by just measuring the height of the column on this scale provided, we can determine the pressure *p*.

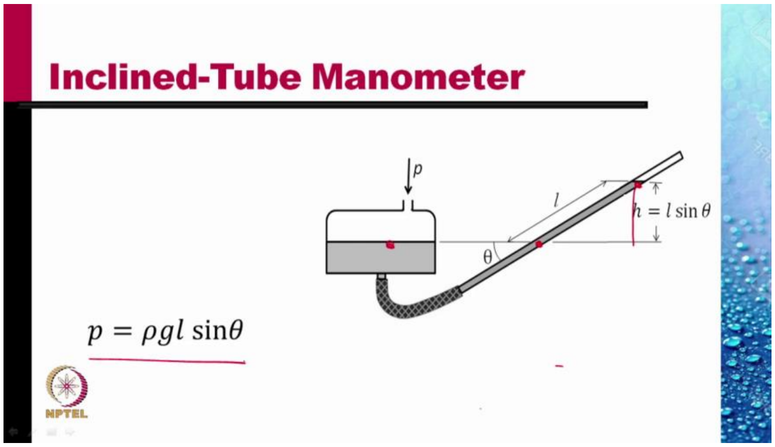
This is used in the conventional blood-pressure measuring equipment. Here at the bottom there is a relatively large reservoir of mercury which is connected to a very fine-bore tube against a scale. It is kept vertical, and when the pressure is applied to the reservoir, mercury rises as a column within the capillary, and by reading the height of the mercury column on the fixed scale, provided, we can calculate the pressure head.

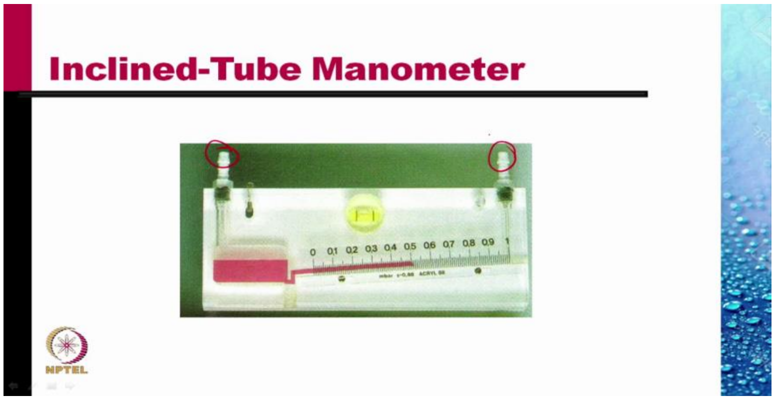
(Refer Slide Time: 10:14)



This too is a reservoir manometer with many tubes, a multi-tube manometer. Here it is being used to measure the pressure distribution about an airfoil**.** This sketch shows an airfoil with a large number of holes. From each hole, a tube runs to one of these many tubes. There is a reservoir too which contains the fluid. And so the heights of these columns give an indication of the relative levels of pressures at the different holes in the airfoil.

(Refer Slide Time: 11:10)





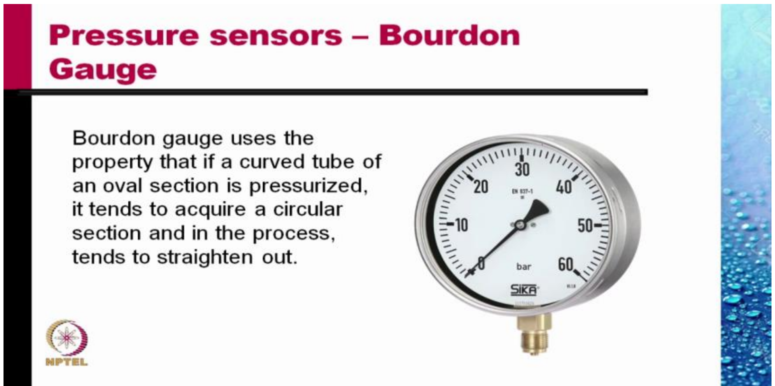
This is another device: an inclined-tube manometer. The pressure difference that we measure is $\rho g h$. If h is small, it can lead to error. So, to increase the value of h, we incline the limb of the manometer at an angle θ. The pressure at this point which should be equal to the pressure at this point, is higher than the pressure at this point by the amount $\rho g h$, but h is $l\sin\theta$. So, the pressure p is $\rho g l \sin\theta$.

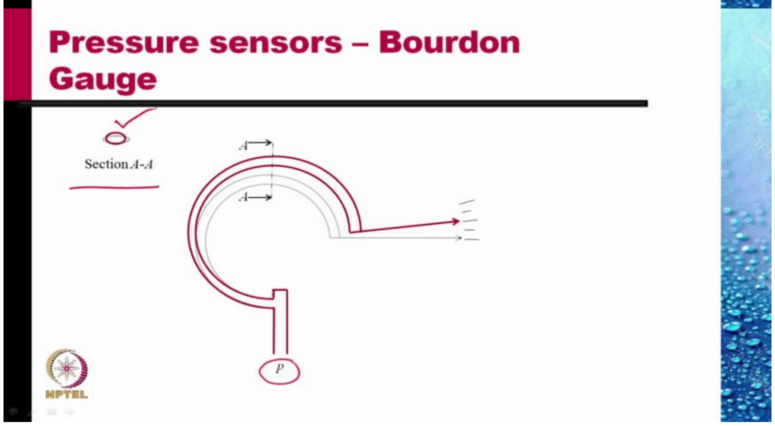
This is a commercially available inclined-tube manometer in which the two pressures are connected at this nozzle, and at this nozzle, and then it measures the difference along the scale shown.

(Refer Slide Time: 12:32)

This is another inclined-tube manometer in which the inclination is variable. The errors in very low measurements of liquid heights are very large compared to errors in larger heights. So, we need more inclination when the height of the column is less, but we can do with lesser inclination when the height of column is more. So, in this commercially available variable-inclination manometer the tube is curved in such a manner that the inclinations for low values of head differences are large, but the inclination at higher values is low. In fact, the tube becomes vertical towards the higher end.

(Refer Slide Time: 13:30)

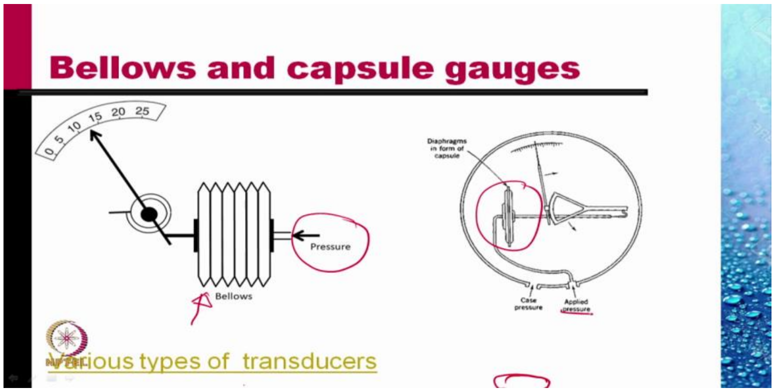




Bourdon Gauge is a gauge that is used to measure the pressure most commonly. It uses the property that if a curved tube of an oval section is pressurized, it tends to acquire a circular section and in the process it straightens out. This we show here: we have shown a curved tube with an oval section here.

As we apply a pressure p at this end, the cross section of the tube tends to round out as shown here. And as the section of the tube changes the curvature of the tube decreases, radius increases. So, it expands out, and as it expands out, the pointer attached at the end moves on the scale and this gives a reading of the pressure. This is the basic principle of a Bourdon gauge - one of the most commonly used pressure measuring equipments.

(Refer Slide Time: 14:59)



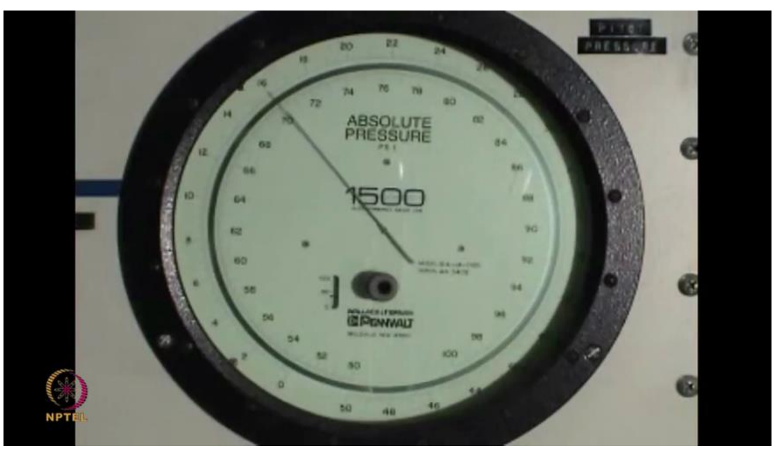
The other types of gauges use bellows and capsules. In this first picture, there is one pressure which is applied on the outside of the bellows. The other pressure that we want to measure is transmitted inside the bellows, and depending upon the pressure the bellows move in or out. And as the bellows move they push the pointer around a scale. More the pressure, more is the reading on the scale.

Similarly, we have a metal capsule here, or a diaphragm in the form of a capsule. There is a case pressure that is atmospheric pressure in most cases, which is applied here. And then the pressure that we want to measure is applied there. Because of this difference in pressure, the capsule inflates or deflates, resulting in a motion that is converted into the motion of a pointer on a scale.

(Refer Slide Time: 16:27)

Tyre gauge based on the Bourdon gauge principle reads the tyre pressure as a gauge pressure about 34 pounds per square inch or 234 kPa. Gauge pressure is the increment of pressure above atmospheric pressure.

(Refer Slide Time: 16:46)

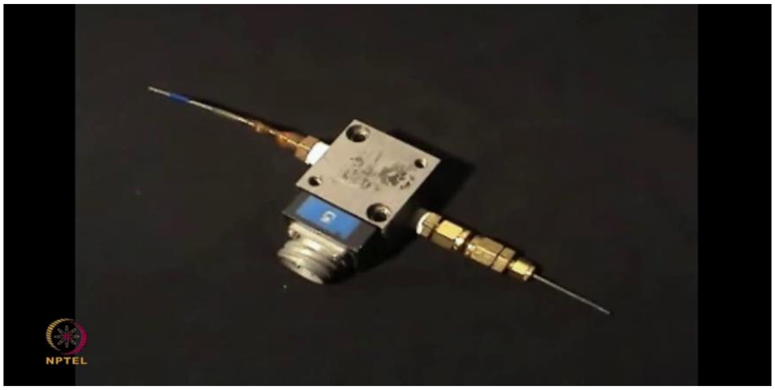


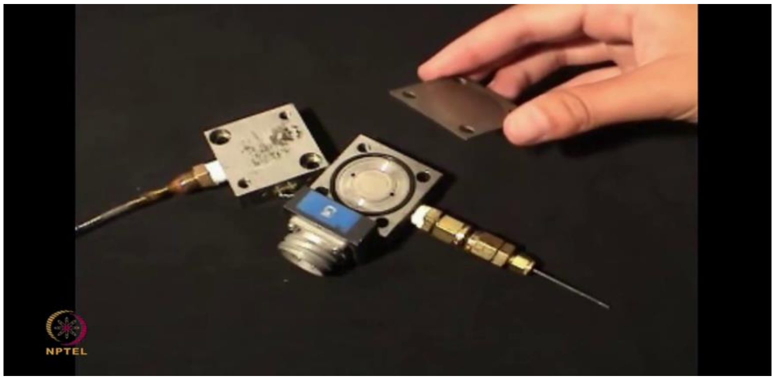
This is another instrument based on the same principle, but designed to read absolute pressure. It reads about 14.4 psi when open to the atmosphere at the altitude where these experiments were done. If we apply pressure above one atmosphere, the reading increases above 14.4 psi. As a vacuum pump draws the pressure down, the reading tends toward 0, on this absolute pressure scale.

(Refer Slide Time: 17:21)

Both these instruments operate on the Bourdon tube principle. The curved tube is connected to the high pressure being read. A higher pressure tends to straighten out the tube and vice versa. The end of the tube is connected to a linkage that drives an indicating needle on the face of the pressure gauge.

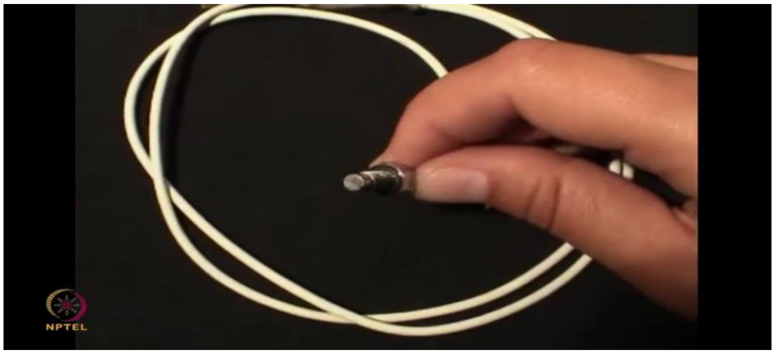
(Refer Slide Time: 17:43)





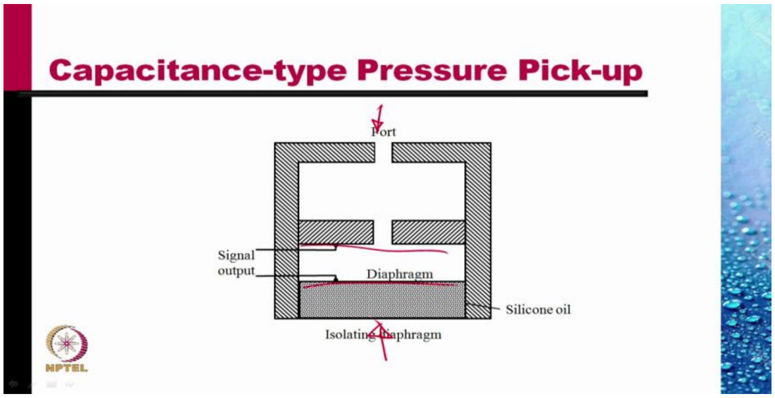
There are other instruments to measure pressure such as this diaphragm-type transducer. A pressure difference across the thin metal diaphragm causes it to flex and it changes the internal capacitance of the transducer, which is sensed electrically and converted to a pressure reading.

(Refer Slide Time: 18:02)



This is a modern Piezoelectric pressure transducer, its tip contains a crystal that responds to pressure changes by generating an electric charge. The amount of charge can be converted to a pressure reading through calibration.

(Refer Slide Time: 18:21)



Professor: Another common type of pressure pickup is a capacitance type pressure pickup. In this case, we utilize the fact that as the distance between two charged surfaces changes, the capacitance changes. And so that results in an electrical signal that measures the difference in pressure that is applied here, and the pressure that is applied on this side. Or one side is atmospheric pressure usually, while the other side is a pressure that needs to be measured.