Thermodynamics of Fluid Phase Equilibria
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Lecture - 02
Zeroth law of thermodynamics and pressure

Welcome back. In this particular lecture we are going to cover review the fundamentals of the first, fundamentals of the zeroth law of thermodynamics temperature, basics for calculating temperature. And we will discuss about pressure and some of the devices which are typically used to find out pressure or pressure differences.

So, this is our learning objective ok.

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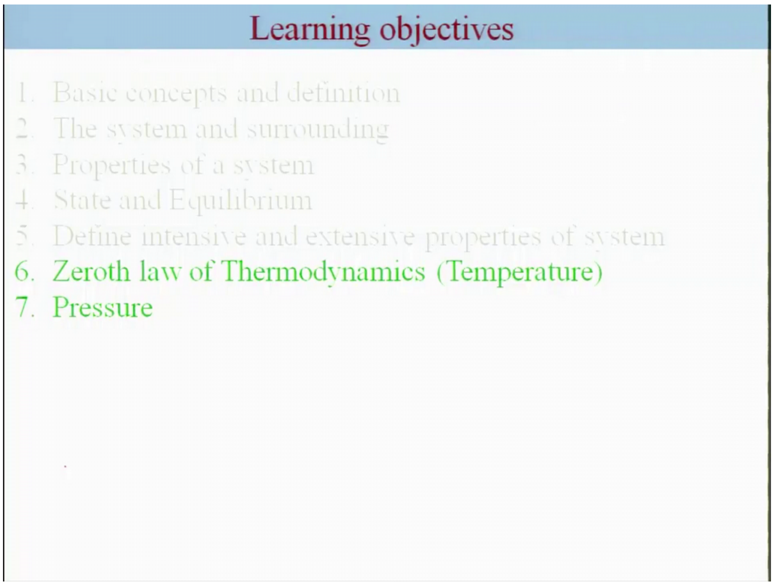

So, let me just go through the first the zeroth zeroth law of thermodynamics; obviously, you all are know this concept very well, but just to summarize.

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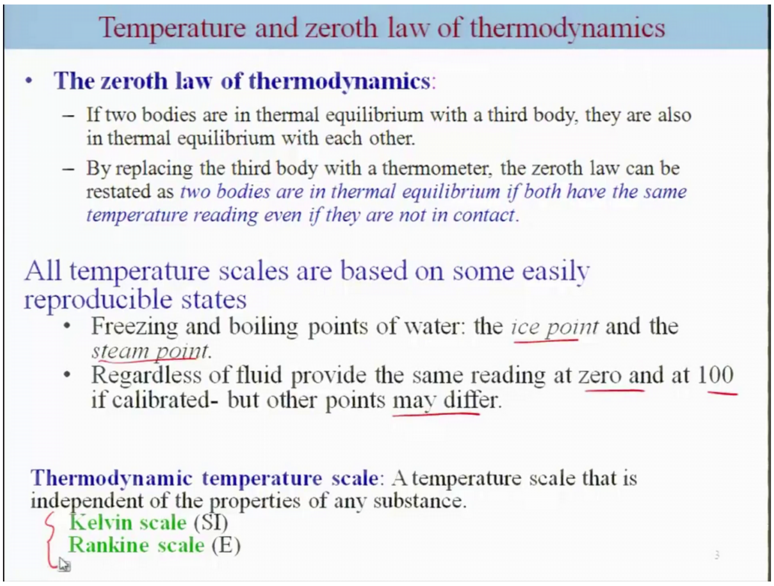

So, what we say about zeroth zeroth law of thermodynamics is that if 2 bodies are in thermal equilibrium with the third body, they are also in thermal equilibrium with each other. And in other word you can replace the third body by a thermometer. And thus your zeroth law can be restated as 2 bodies a in thermal equilibrium if both have the same temperature reading even if they are not in contact.

So, that is become the basically the zeroth law of thermodynamics. Now practically it means that we need to understand how the termometers work ok. Now all the temperature scale, which has been devised are based on some easily reproducible state ok. And the states is basically ice point and steam point. So, basically 0 degree and 100 degree ok. So, the point is that you can consider any particular fluid, and you can scale it in such a way that you get 0 degree and 100 degree.

But the point between 0 to 100, if not even if you calibrate only the 0 and 100 the other points may differ. The reason being that the thermal expansivity of the fluid vary from each other. And that is why such a thermometer or not commonly used. The one which is used is basically based on either idle gas thermometer, which is which shows that it is independent of gases which are considered. And the scale is a linear as a function of a temperature in other word the pressure is linear as a functional temperature ok. And thus, you can change the gas and still you can achieve the same points, and you can still calibrate it well. Or the same thing which you can use in idle gas thermometer is by considering absolute temperature scale, which is based on second law of thermodynamics. And both are equivalent, it can be shown.

So, in case of a absolute thermodynamic scale or thermodynamic temperature scale the examples are Kelvin and Rankine scale ok.

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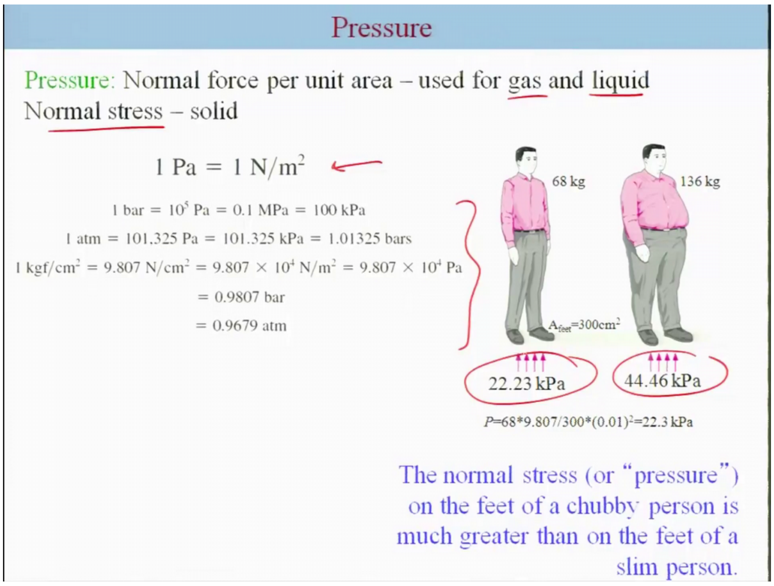

Now, pressure of course, pressure we all know is it is a normal force per unit area, it is typically used for gas and liquid. We do not use the pressure for solid, we use stress normal stress for solids. And a unit depending on the SI unit is this, other units are given here. Now it is very clear that the pressure executed or felt by the feet of a chubby person is substantially larger than that for slim person ok.

Now, what is variation of pressure?

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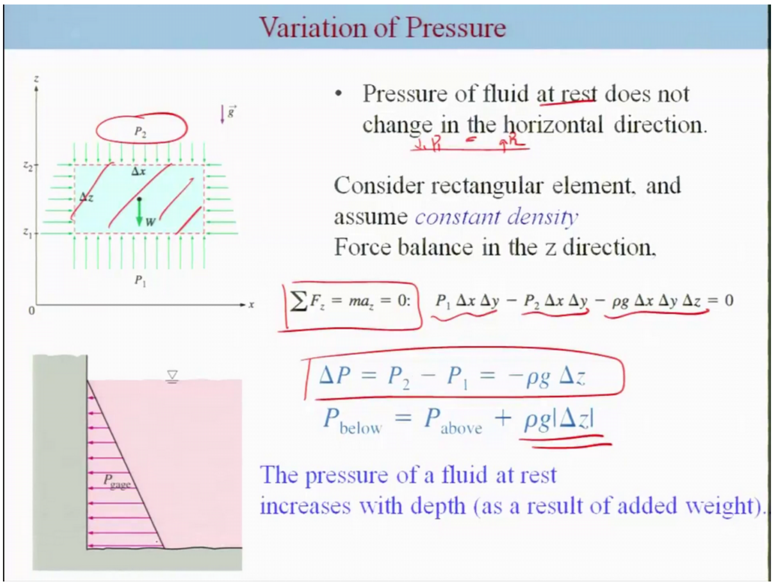

Now, fluid or pressure for fluid at rest does not change in the horizontal direction ok. So, that means, there is no once it is at rest because there is no flow. So, the force is along the horizontal directions are going to be constant ok. So, this pressure, and this pressure if at rest is going to be same ok.

Now, let us consider a rectangular region; which is this ok. And then do a simple force balance for this particular mass within the rectangular element. So, the force balance should be because it is not flowing should be 0. So, which means this is basically the force acting on it ok, on this from below. This is the force due to the air ok, or due to the fluid above it acting on this particular element. And this is basically the mass or the weight of mass this is the weight multiplied by rho g multiplied by the volume, which is nothing but the weight; so if you do a simple mathematical calculation and take it out the common term, what you get is nothing but that P 2 minus P 1 is nothing but minus rho g delta h. In other word, p below is more than p above by this value ok.

So, the pressure increases linearly with distance, as we go down in depth, because of the added weight of the fluid.

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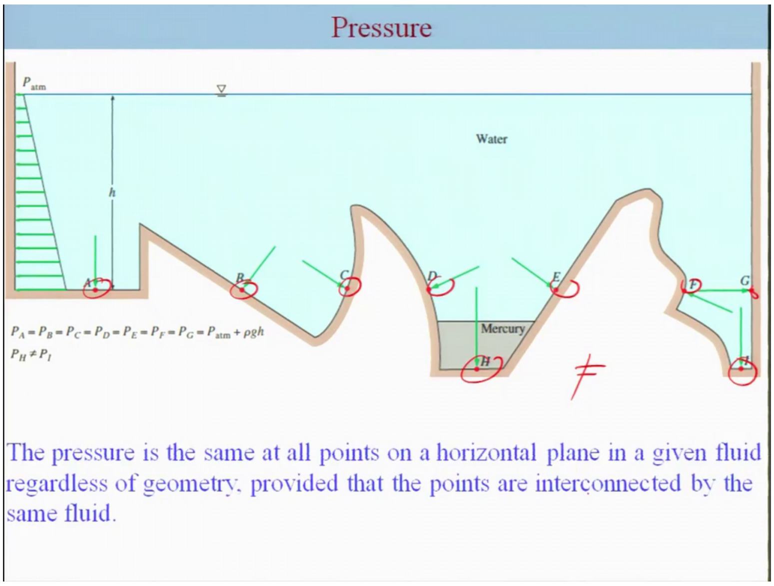

This also tells you that the pressure along the horizontal points for a given fluid will remain constant, though the pressure in depth increases. But this (Refer Time: 05:23) tells you that the pressure here, same as here, here, here, here, here and here. And pressure here and this are not same. For simple reason is this is a different fluid ok. So, you need to have the same fluid in order to have the equality of the pressure ok.

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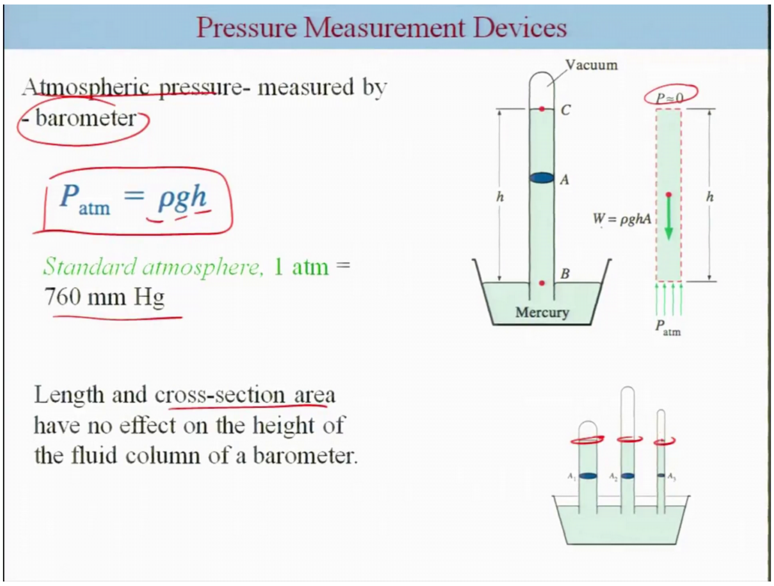

Now, what are the measurement devices for pressure? One is the simplest one is the barometer; which is used for atmospheric pressure ok. So, for example, this is a simple device due to the vacuum, the pressure here is this you can apply a force valence, and you can show that p atmosphere is nothing but the density of the fluid which we consider; which is nothing but the mercury, the g gravity and the height which is being which is rise due to the pressure. And for one atmosphere this is nothing but 760-millimeter HG ok.

Now, it also tells you that the cross-sectional area of the tube has no effect on the the height of the the barometer.

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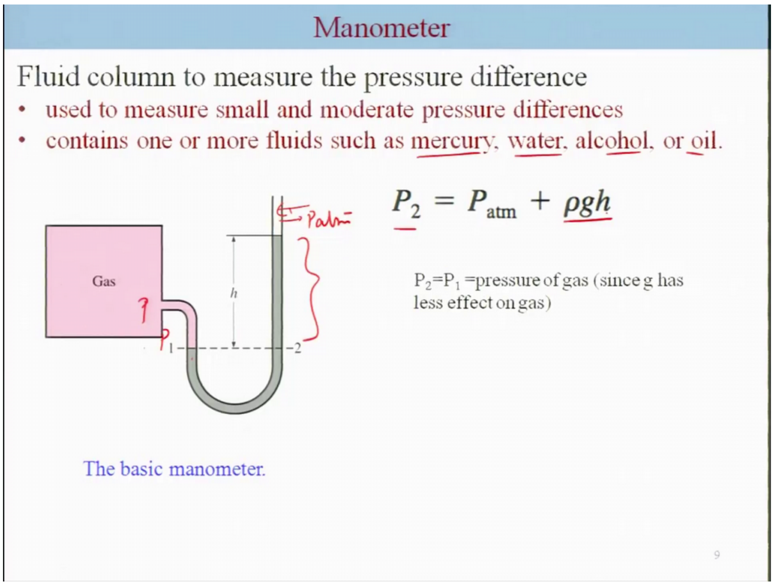

And even though you use different column, the height will remain the same ok, because of the simple balance here. So, in addition to barometer we have also other devices. For example, if you are interested in measuring the pressure of a container having a gas, one can use fluid column to measure simple pressure difference, and that can be used to measure the pressure of the gas container ok. Otherwise fluid could be any fluid mercury water alcohol or oil.

So, this is an example here. For example, if you are interested to find out the pressure of this gas. Since gas is typically has very, very small density, compared to the heavier fluid. So, pressure here would be same as pressure P 1 ok. Now P 1 pressure because of the force balance this is not moving. The P 1 P 1 pressure here in this side and this side should be same, because of the force balance. So, P 1 and P 2 should be same.

So, and here is the p atmosphere ok. So now, you can simply use P 2 is equal to p atmosphere ok, plus the rho gh ok. So, this is a simple way to calculate. So, thus; that means, if you calculate P 2 you know exactly what is P 1. And that means, the gas of the container.

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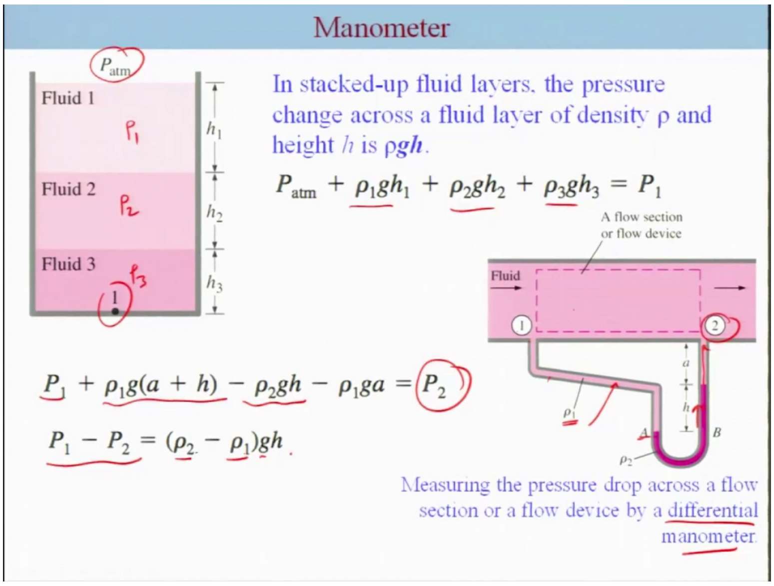

Now, in addition to this you have manometer, which many times you stack up the fluid layers. And in this case, you have 3 fluids having these heights. And one can relate p pressure at 1 with respect to P atmosphere, and the density of the this fluid with different heights. So, one can simply use P atmosphere plus the rho 1 gh 1 plus rho 2 gh 2 plus rho 3 g h 3. And this is exactly what has been done to achieve P 1 ok. One can also use differential manometer in order to find the pressure difference between 1 and 2.

So, we can start from P 1 ok, and go down and the height, it does not matter what kind of geometry we are using, what we are interested is, it should be of same fluid and effectively the height of the from this point to whatever for example, this point. So, P 1 is this plus rho 1, which is the fluid here which we are interested to find the difference from this this 2 points. So, rho 1 g plus whatever the height from this point till a, which is nothing but a plus h and that is what you get rho 1 g a plus h.

Now, this pa is same as whatever is at pb. So, we do not we we go from here to directly to here. And now we are going up in the direction ok. So, we are going to subtract the the rho gh from this term. So, that will be rho 2. Because this is rho 2 g h here. Now from here to here we are going to subtract minus rho 1 g a and thus we are going to achieve find out the pressure at 2.

So, if you readjust, this term we get p 1 minus P 2 is is equal to rho 2 minus rho 1 gh. So that means, the pressure drop from here to here is equal to the difference in the density of this fluid which we of this with respect to rho 2. So, rho 2 minus rho 1. So, rho 2 is usually is going to be much, much larger than rho 1 ok. So now, we can do a simple example here to to exercise this.

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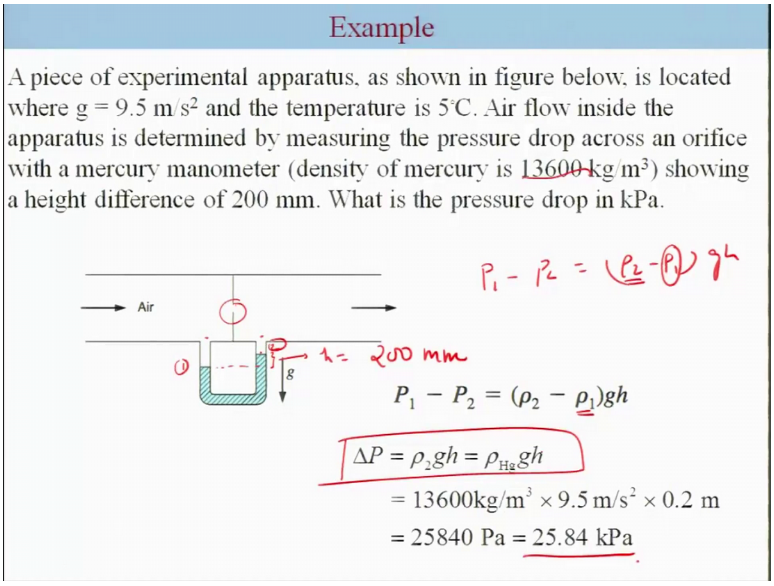

A piece of experimental apparatus as shown in the figure below ok, is located where g is 9.5 meter per second square, and the temperature is 5-degree celsius. Air flow inside the apparatus is determined by measuring the pressure drop across an oriface, which is nothing but this ok. With a mercury manometer ok and the density is equilibrium, showing a height difference of.

So, this height is 200 millimeter ok. So, what is the pressure drop from ok across the orifice? So, in the word what is the pressure drop? Let us say from here to here and ah. So, the pressure drop from 1 to 2 can be written as simply here, why because of course, the density of the air is extremely small, and this height difference does not will not bother. The density of air is close to 1.2 kg per meter cube ok. So now, we have done this exercise. Before that that pressure p 1 minus p 2 is nothing but rho 2 minus rho 1 gh. So, ok rho 2 is of course, the density of the mercury rho 1 is density of the air.

Now, this we can ignore also because 13, 600 minus 1, 1.2 is going to be negligible. So, for measuring approximation we can simply write rho Hgh, and this comes out to be this value ok. So, here we ignored rho 1, and simply written rho gh hg, and thus the value is ok. So, so, that will be the end of this lecture. So, where we discussed very quickly the temperature concept, and as well as the pressure ok.

So, we will see you next time, and where we are going to introduce rather review the energy conservation in the first law of thermodynamics.