Engineering Thermodynamics
Professor Jayant K Singh
Department of Chemical Engineering
Indian Institute of Technology Kanpur
Lecture 03
Temperature Scale and Pressure

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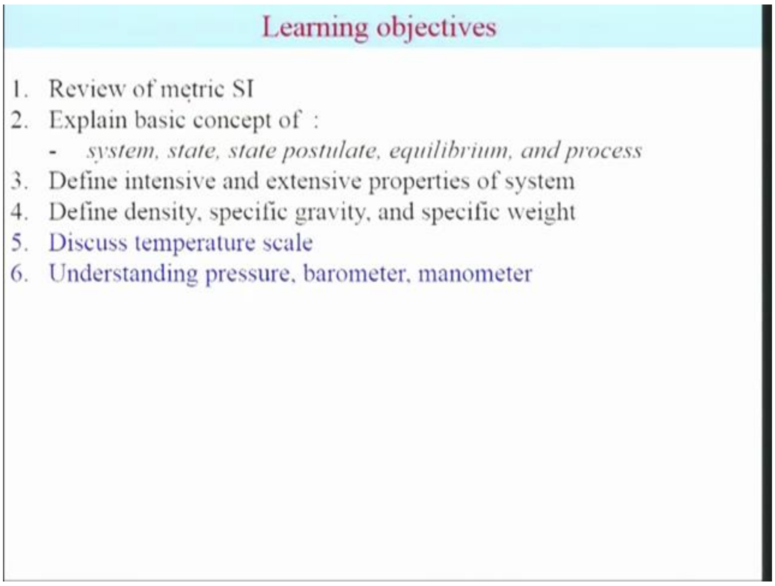

Okay. Welcome to the introductory section of this course we are covering the introduction and this is a third part of the introduction of this course. We have to already discuss the metric SI units. So, metric SI units are the concept such as system state, state postulate, equilibrium, process and process path. We already defined intensive which essentially is not dependent on the size or the system and volume and extensive which depends on the mass, volume.

So, the example of intensive is temperature, pressure and extensive would be like volume itself and mass. And then you have define density is specific gravity and specific weight you can turn any extensive variable to intensive variable by dividing with mass or volume. Now in this part of lecture we are going to discuss the temperature scale and discuss the pressure and how to measure such pressure of pressure differences using barometer and manometer.

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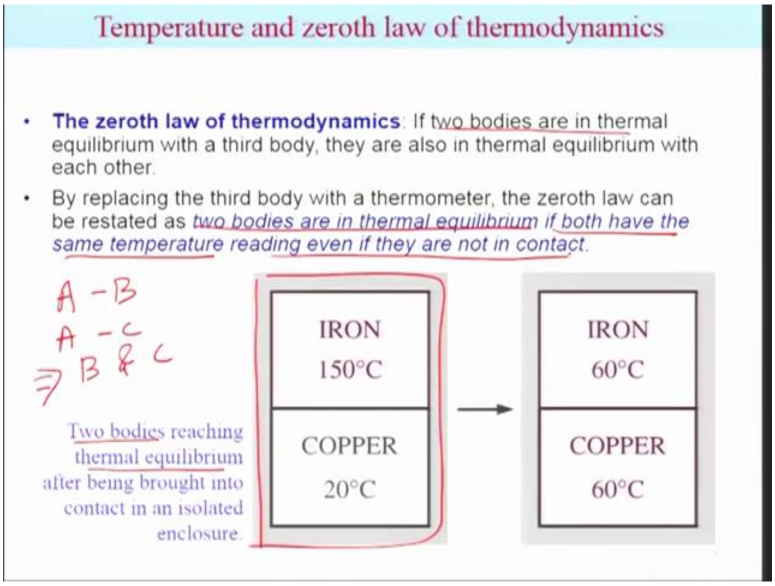

So, let us start with the temperature when you talk about temperature (())(1:18) think of is a feel of the hotness or coldness of an object. But defining a value to that is extremely difficult right. You can make mistakes, for example at a room temperature you can touch a steel material you can feel that is colder than any other material such as wood in the same system. So, just based on your sensation feeling we are not going to is difficult to define a value to get it.

So, that you aware from the natural environment or (())(1:47) that, when you put object hot object on top of a cold object eventually both the objects turn out to have the same sensation in some sense. On over you know that the temperature decreases if you keep a hot coffee on the table at room temperature. So, there is a heat transfer from the high temperature so called the feeling based high temperature to a low temperature.

So, this is we are going to defined as (())(2:12) thermodynamic. So, let us take an example, so you have what you have done is you taken a Iron object which is at 150 degree Celsius put on top of a copper object which is 20 degree Celsius and we have isolated it this is isolated in some sense okay. After a while you see the both reaches a certain temperature. Now this is we call it that the both bodies that is 2 body reaching the thermal equilibrium are same temperature stands for thermal equilibrium.

So, this leads to a zeroth law of a thermodynamic which says that if you two bodies are in thermal equilibrium with a third body, then they also in thermal equilibrium with each other. So, you can take for an example A with B and A with C if both system are at thermal equilibrium this will imply that B and C are at thermal equilibrium and B and C or in this case particularly A could be a thermometer, for example you can measure thermometer get the same temperature you can measure another system you get the same temperature which essentially which system 1 or 2 are at equilibrium.

So, this is what the second statement says that by replacing the third body with the thermometer that zeroth law can be stated as two bodies are in thermal equilibrium if both have the same temperature reading even if they are not in contact so this is the feel based concept okay. But we will describe it more, that how do you define this case and this was the actually challenge in earlier age, why they came up with the system such that this can reproduced call you now we can reproduced the same kind of systems or same kind of references so called.

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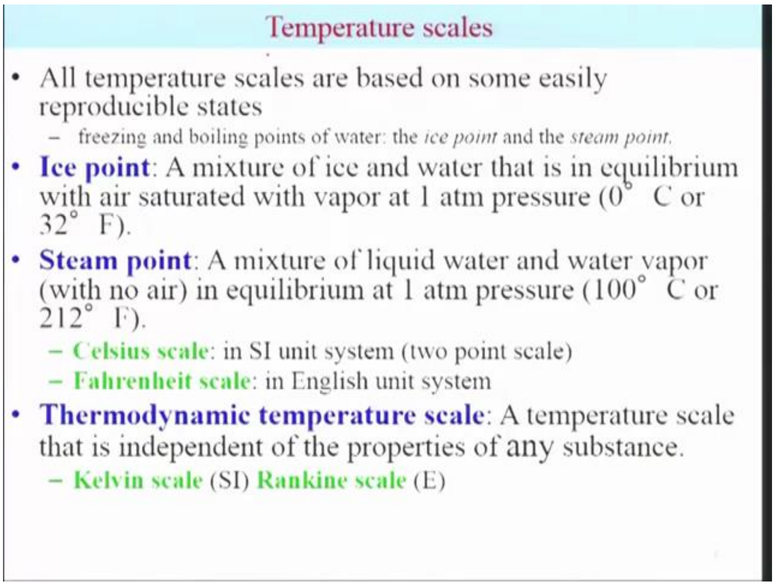

So, the naturally their content we or the fluids we considered was water because it was available for sure. So, all temperature scale, so there are many temperature scales available they are based on some easily reproducible state. So, they commonly use freezing and boiling point okay or at atmospheric pressure okay. Now they are defined as the ice point and steam point so let us look at what is the ice point, ice point is nothing but a mixture of ice and water that is in equilibrium with air ok saturated with vapor at 1 atmosphere.

So, at this conditions we have air as well as you have water vapor because you are conducting this experiment at certain condition which is open to air okay. And then we have this steam point, which is a mixture liquid water and water vapor with no air. So, we have defined something called zero Celsius and 32 Fahrenheit, these are the two different units which I used okay. Celsius is a scale which is you now of SI unit and Fahrenheit is a English unit okay. And then there other point which is a much higher on the temperature is a steam point.

So, steam point is 100 degrees Celsius or 212 Fahrenheit. So, these are the 2 scales which are based on this reproducible state or based on water okay. But then it depends on the fluid which you are using and the idea was not to just stick to a ratio, then independent that came of the idea with thermodynamic temperature scale which is independent of any fluid which we use and the two scales which came up which we have designed that people have Kelvin scale which is SI and Rankine scale which is English.

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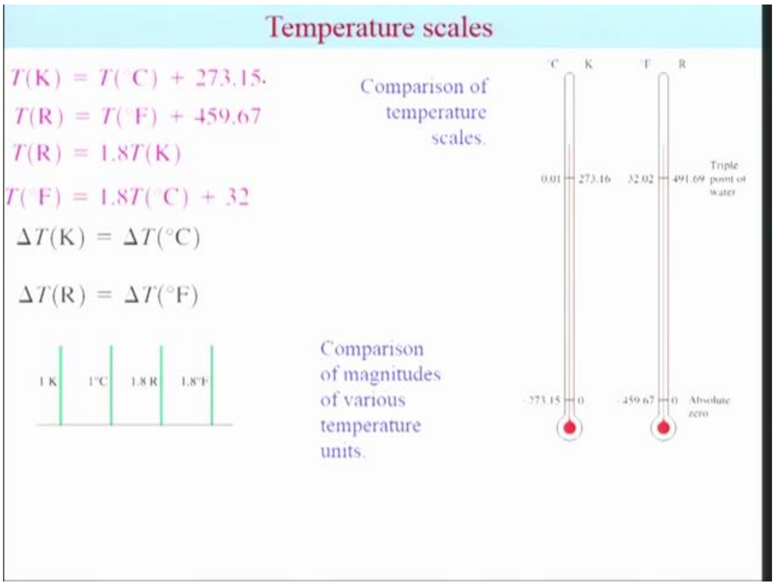

So, let us look at it how it can be related, you know very well that Kelvin is related temperature scale in Kelvin is related to Celsius. That means by this relation which is temperature of any Kelvin unit is Celsius + 273.15 and then you have this ranking and a ranking in the Kelvin K is there is the ratio 1.8, so that temperature varies in Rankine scale is just a 1.8 times the temperature in the Kelvin scales. The difference here is same for the Kelvin in Celsius and that is true for the Rankine and Fahrenheit. So, that means the English and the SI units are known as made in a similar line okay. There is a one different here that earlier, when it was designed the Kelvin scale it was based on ice point 273.15 that means in the when the ice is formed.

But later on they found that the more precisely (())(6:23) state is a triple point which is 273.16 and that is why the value is a set. And that is why you can see here this scale of this corresponds to this one. But once you have done that you cannot change the Celsius, the definition is still same that is why it is 0.01 degree Celsius corresponds to 273.16 Kelvin okay, or also the other unit which we are going to use.

So, we are talking about intensive variables which are extremely useful right. So, you we talked about that you can define state will of incompressible fluid by providing two intensive variables okay. For a single phase temperature pressure is fine, but for oil you can use temperature at specific volume. Specific volume is variable even if it a there is a phase change such as water going from the liquid to the vapor, but the pressure is dependent on the temperature when there is the phase change.

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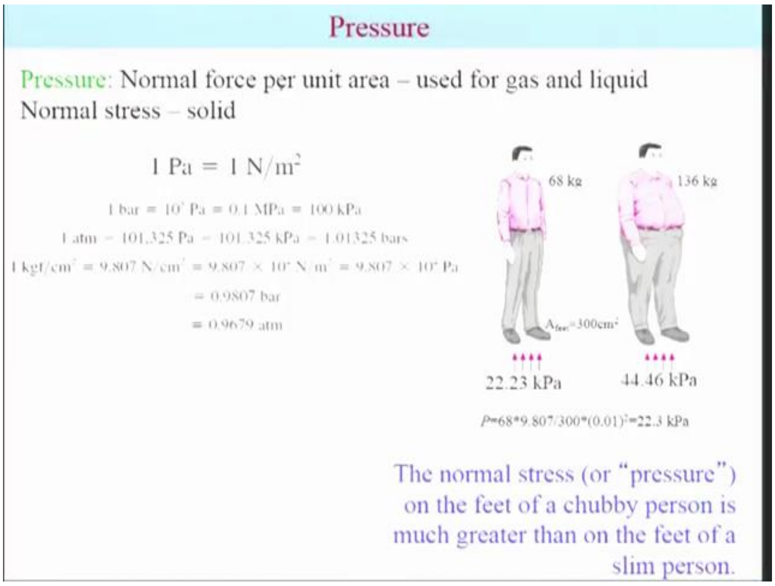

So, we talked about that the pressure is extremely useful unit for our thermodynamic analysis. It is say, a simple definition normal force per unit area it is commonly used for gas and liquid, for the case of solid we use stress. Now it is pressure is a scalar or vector, you will say the pressure is a scalar for simple reason that you have already taken the directional force you are saying normal tangential So that makes it that the direction is already incorporated or the other hand stress is not, stress is you can stress turns out to be (())(7:49) quantity. So, now pressure is the unit is 1Newton per meter square in SI unit we also can say in terms of Pascal this is a unit for Pascal. This is a small value by a typically which we enquire as a encounter in a daily life is quite large such as 10 to the 5 Pascal and bar or atmosphere.

So, the commonly used units are bar/atmosphere and this kilogram forced per centimeter square and this is a quite useful in a different country such as Europe, they used it quite often here looking that is like 1 kilogram force which essentially means you have fixed the mass by1 kg and the g in the g is a 9.807 and hence you have this specific value. You can clearly calculate the pressure active on our feet by knowing simple relations say, so you have the weight and clearly see based on this analysis that a pressure for this person acting here is along 22.23 kilopascal. So, this is your mass is g and the area of the feet we assuming the area on the feet for this person and the chubby person is same okay, that could as the assumption considering that this person is experienced twice the amount of pressure on his feet so, through that is analysis you can do that .

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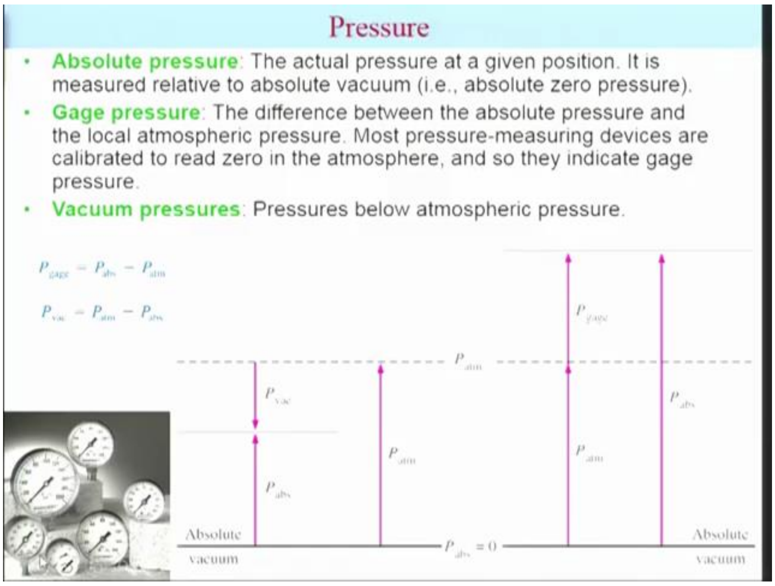

Pressure when you measure like pressure of a your tire you measure with respect to atmosphere that we know that that is why always we measure in terms of something called gage pressure. But let us look at the absolute pressure first so which is basically pressure at a given position it is measure relative with the absolute vacuum. So, what does it mean that you have no gas nothing in a container and that gives you a vacuum and there is no molecules which are imparting any pressure on the container and lead into the pressure we can refer as a vacuum pressure which is as here.

So, you have this absolute pressure of vacuum pressure is zero and then you have you this let us say this pressure which you desire. So, this becomes a pressure again this is absolute okay. And this is value here and this is the let say atmospheric pressure. So, the difference for with respect to atmospheric pressure is called gage pressure, so this is the one. So, gage pressure is nothing but P Absolute 9 - P atmosphere. So, when you Gage pressure measurement unit are refer in this form they are actually tuned or calibrated such that it there the reference point becomes the atmospheric pressure whatever the difference is gage pressure and the vacuum pressure is the pressure below the atmosphere. So, in this case for example you had this P atmosphere which is larger than the actual for the absolute value and pressure and hence the difference gives you the vacuum pressure okay. So, these are the two minimum that okay.

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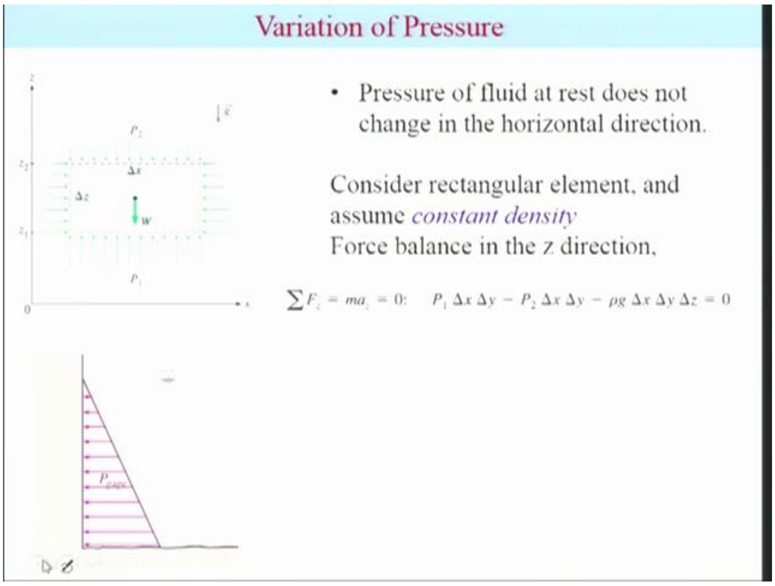

So, let us now look at the variation of the pressure, so you can take a rectangular element which is defined in this one, so this is are the rectangular element okay and the shaded blue vision is a fluid. Now you can do a forced balanced in the horizontal direction, the horizontal direction you can do a forced balanced you can clearly see that the pressure should be same at each part, so, yes in a just we will do a forced balanced in the vertical direction. So, the vertical direction you have the pressure let say you have defined pressure at this point P 2 okay which is acting on this element of the fluid and the weight of the fluid is w okay. And then there pressure is acting on a other side of the fluid is P 1. So, if we you do a forced balanced, you know that the P 2 all this case the P 1 times the cross sectional area will be the force.

Now if the cross sectional area would be your this delta X okay and the Y direction which is perpendicular to this line okay. So, that becomes your forced acting on the fluid from bottom and then you have another term which is here which is basically multiply the delta x or delta y. So, that becomes the force active here, so this could be your F 2 for example okay and then the weight is downward, so you have to look into the weight, so you have Rho g and this is the volume.

So, so this must be zero because it has to be balanced okay. Then you can do the mathematics here because this we will cancel out so what remains is, P 2 - P 1 which is equal to - Rho G delta Z. So, tells you that the P 2 is smaller than P 1, because Rho is positive, g is positive and we have as a delta Z to be positive. In other word you can say that Rho P below is P over + Rho g absolute value of delta Rho and Z okay.

So, that is what we can we know that the typical gage pressure or the pressure will look like in this form and (())(12:59) form. So, which essentially you can understand that this fluid here is balancing the weight of the other fluid and hence the pressure should be more or so that is what we say the pressure of fluid at rest increases with depth as result of added weight now the pressure variation is depends on the fluid density.

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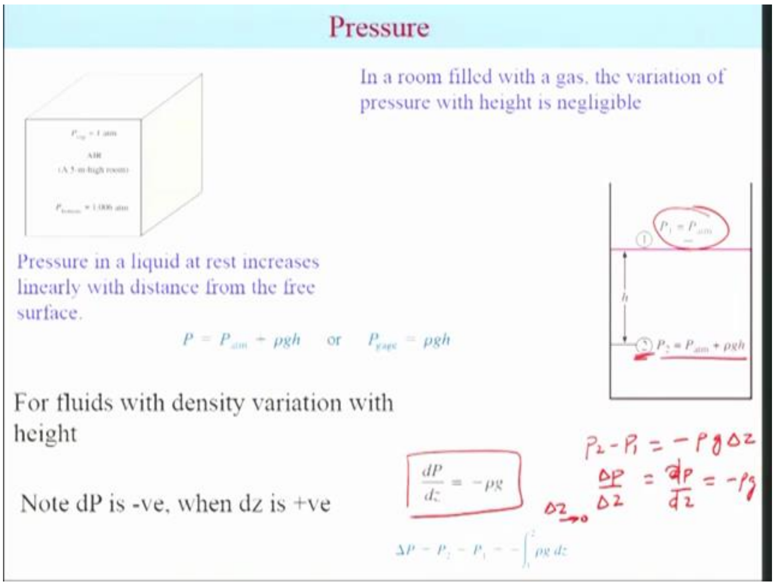

So, you consider this particular room, you are asking the pressure somewhere top here and below, which we separated by few meters and the pressure would be extremely the difference would be extremely small and reason is the density of the air is very small. So, on the other hand that is not true for liquids so, because the density is quite high so we have to consider that variations in the pressure.

So, this is an example, so this container containing a fluid, at the top is the layer of the fluid the pressure is given as P atmosphere because is a open to the atmosphere and somewhere at a somewhere in the fluid let say 2, the pressure is simply given by P atmosphere + Rho g h okay. If the density is variable okay then you have to consider in the differential form. Because we call that in a previous one we talked about P 2 - P 1 is equal to - Rho g delta Z.

So, this is nothing about delta P by delta Z and then if present in delta Z and then Delta Z goes to Rho g. So, you can find out the delta P by integrating this expression or that is what this is given here okay. So, let us look at some examples like what implications of pressure. We talked about the pressure allow the horizontal plane for a given fluid should be same okay. The variation is only when you move along the vertical plane okay.

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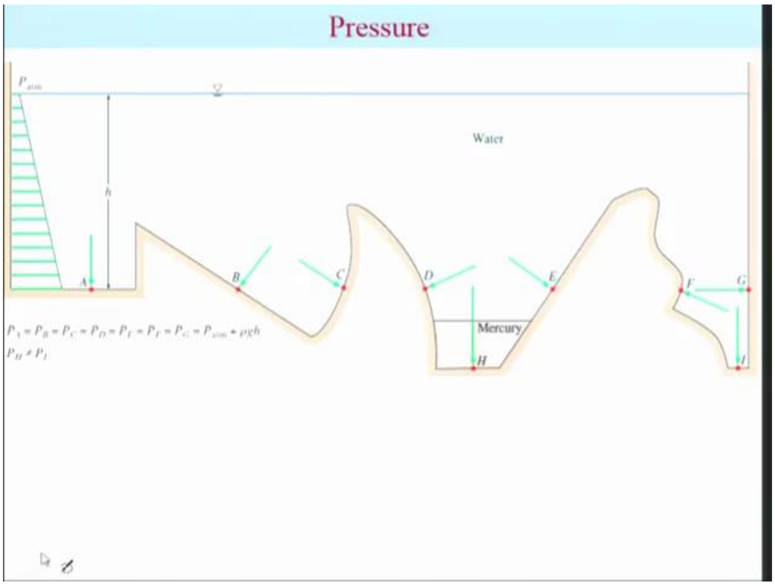

So, this is a very nice illustration, so here you have water and mercury in a container which is a very unusual geometry and it you can clearly point out that the pressure at A, B, C, D, E , F and g points should be same and the reason is they are at the same horizontal plane. But h and I pressure here is not same as they are not same and the reason is though it is at the same horizontal plane, but they have a different fluid. So, they contain different fluid and as we have to make use of the differences in the density we will talk about later okay.

So, that means the pressure it is a same at all points on the horizontal point in a given fluid regardless of the geometry provided that the points are interconnected by the same fluid. So, it is extremely important that they should be having same field okay. And it has a very repercussion this state has many repercussion one of the repercussion is Pascal's law which is originated from that.

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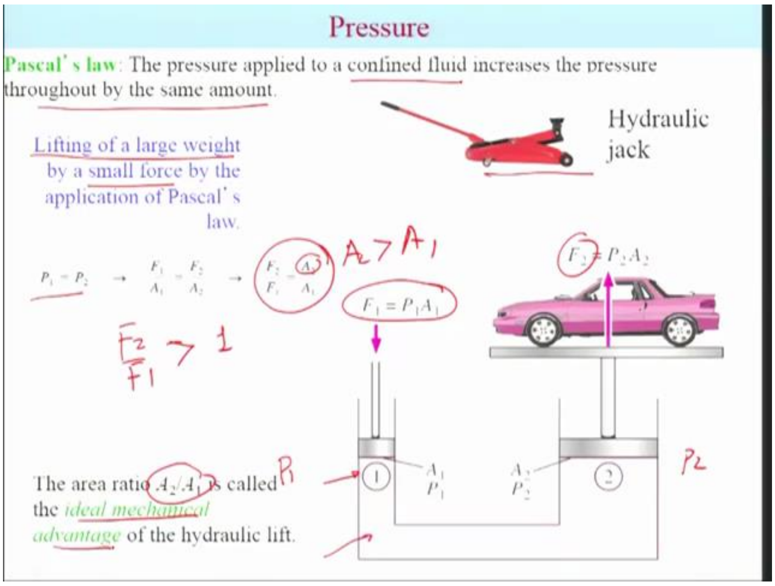

So, it says that if you apply a pressure to a compile fluid it increases is the pressure throughout by the same amount and it is application is in hydraulic jack, this is just one example. So, based on this you can lift a large weight by a small force. So, let us look at it how it does. So you consider this jack in this schematic diagram, you have a single fluid here which is represented by this color. And you apply a force F 1 at this end, this leads to a certain pressure like say P 1. Now once the pressure is you know this system is equilibrated in so we are assuming that is quasi equilibrium state you the pressure P 1 should be same as the pressure at P 2 because they are at same horizontal level.

So, now what about the force F 2 so you can look at it P 1 is equal to P 2 you can find out the forces and it is essentially means you can come up with this expression F 2 by F 1. Now F 2 by F 1 is it greater than one or less than one. Since A 2 is much larger that A 1, it means this much larger than 1, essentially you have increased that force by many times and that is the reason that you can lift a big car by applying a small force there.

So, it has it has wide applications and this ratio A 2 by A 1 is also called ideal mechanical advantage of the hydraulic lift. So, how do we measure pressure, so you can measure atmospheric pressure and this was the first time it was done by Italian scientist and that is why the name comes out, so I will talk about this, so let us take a look how it is done.

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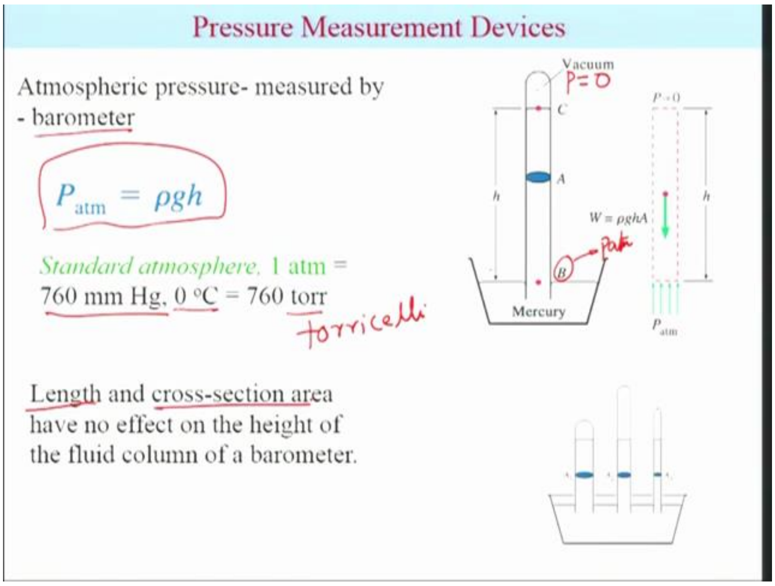

So, you take tube of a let say Mercury and invert it in a container of mercury. So, what happens is so you have such a situation finally and you have two points let say you have point B, so what is the pressure at B, it is going to be atmospheric pressure because this container is open to atmosphere and at the end of the tube there is a small vacuum or even if it is a vapor is so long so small in volume and light that you can still consider to be vacuum.

So, this pressure here is going to be zero and this pressure here is going to be atmosphere. Now you can do a force balanced okay and if you do a force balanced you will come up with this expression that P atmosphere is nothing but Rho g h, where h is the height of the mercury from the top of the containers mercury here.

So, this is a way we calculate atmospheric pressure and this equipment or device is called barometer. So, it is standard atmosphere is 760 mmhg at 0 degree Celsius, so 760 mmhg is a 1 atmosphere and the reason for that is at 1 atmosphere 760 mm of hg is raised that means h is **base** basically is 760mm okay. But this is at a zero degree Celsius and this is also called is equivalent to 760 torr and torr is basically name after Italian scientist any is a twice Torricelli so let me just write it.

So, this is mean after the Italian scientist now using this force balanced you can clearly see and clearly make out the days more effect of the geometry of the tube. If we increase the width if we increase the height of the tubes itself it is not going to the effect. So, length and cross sectional area has no effect on the height. If it is one atmosphere you are going get 760 mm hg, irrespective to whatever tube we are going to use okay. So, this is an illustration which clearly says that okay.

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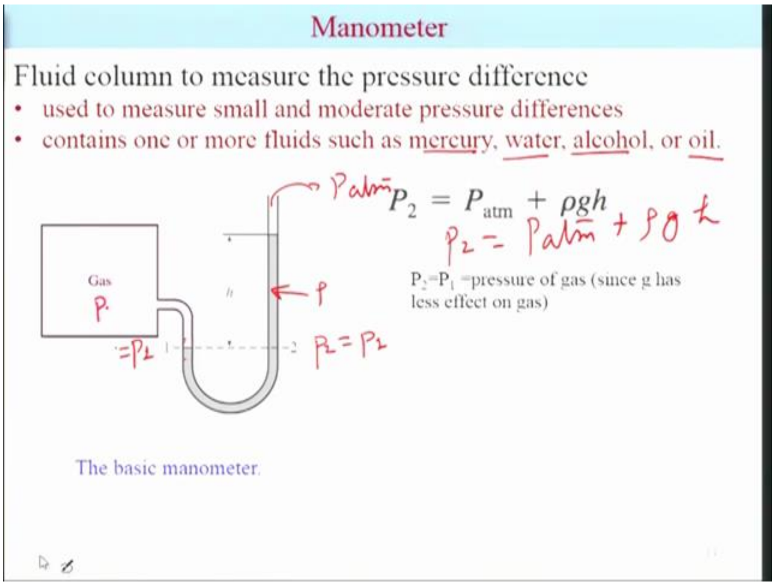

So, let us apply so little bit more on the pressure. Now if you are interested to let say if you take a container the gas and you want to find out the pressure of the container which contains gas then how do we do that. You can apply simple manometer and this is an illustration. So, you have a gas and you attachment to this tube containing a fluid, this fluid could be anything it could be mercury, it could be water or alcohol or oil okay. And you are interested to find out the pressure here let say the pressure here okay p.

Now since is the gas and you have know that the gas density is quite low you can assume that the pressure here is same as the pressure here at P 1 okay. Now because of the mechanical equilibrium the pressure here in this fluid the gas should be same as in mercury and whatever the fluid you are using right. so, and now because of that fact that the whole interpretation be same, the pressure should be same as P 2, so P 2 should be at P 1. So, essentially you now you can correct this P 2 to atmosphere which is open here and you can come up with the expression.

So, the P 2 is nothing but P atmosphere + the density of the fluid which you are going to use and G and this height of this. So, this is simply Rho g h right, so this is a basic manometer usage.

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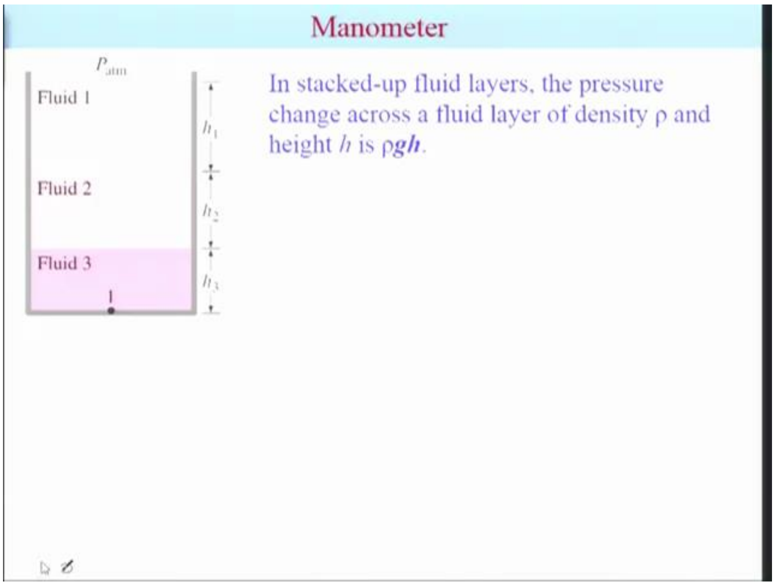

In many cases in many industrial applications are other applications so there are many fluids which are stacked up which are these fluids are typically immiscible fluids okay. And you can make use of these fluids for in manometer as well. So, uh how do you do that you remember 2 things one is of course that the delta P pressure change in a fluid simple Rho G h for continuous fluid same fluids and P below is greater than P ever okay by Rho g h okay.

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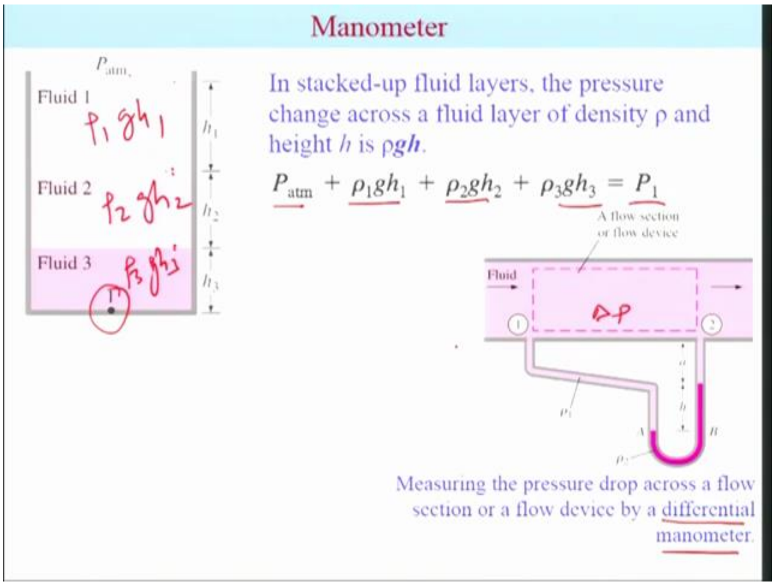

So, lets us will look at it, so in this case you have a fluids 3 fluids and you have to find out the pressure at bottom one that is represented by one here. So, you take pressure at the top and add up the different contributions this come from Rho 1 g h 1, this is Rho 2 g h 2 and this is Rho 3 g h 3 okay. These are different pressure differences from this point to this point, this point to this point and so on and that is why you are going to get the pressure at 1 okay.

We can make use of this in a flow and that is why the fluid becomes quite useful in many devices such as valve what is the pressure drop across the valve or for that matter pump, you can make use of similar kind of devices to calculate the pressure drop. So, one device for that is differential manometer okay, so you have a fluid and you have interested to find out the delta P between these two points okay. There is the flow that means there is the pressure gradient okay.

So, now in so in here is the fluid okay. And you assuming that the stress that density remains the same at here and so this is A point this is B point. So, the pressure at A should be same as pressure at B okay. And so you are if you so that means let me this write starts writing here. So, this is your P 1, the first we have to do is find out the pressure here at A, which is nothing but p1 + Rho g (a + h) because this is the height which you are talking about from here this is a + h. so, pressure here for the same fluid is nothing but P 1 + Rho g h.

So, this is Rho P at A then this same this is same as P B and then it is going up so we have to decrease it. So, that means Rho 2 g h is this part and then you have this Rho 1 g h okay and that is how you are going to achieve P 2 okay. So, if you do this analysis (())(24:06) the value of the change in the pressure turns out to be simply Rho 2 - Rho 1 multiply with g h okay. So, we can end this lecture by doing an example, this is an example.

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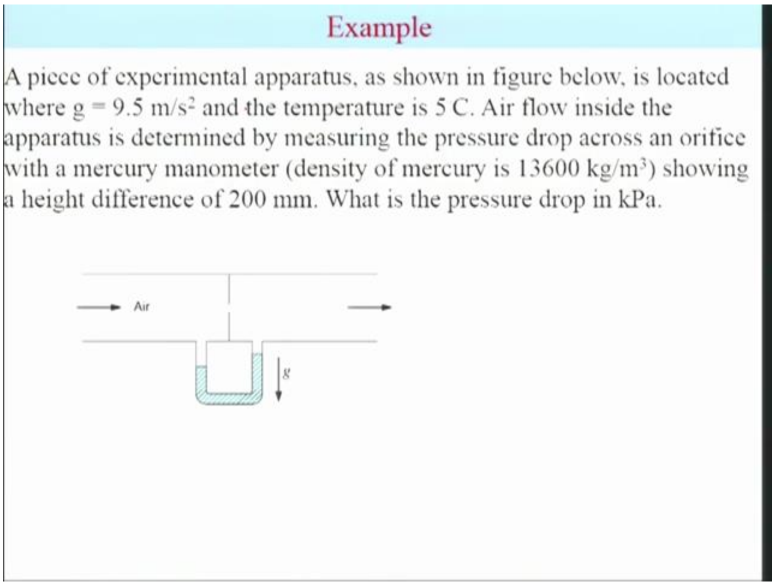

So, you have a piece of experimental apparatus as shown in the figure, where is air is passing and we have using g is equal to 9.5 and that temperature is 5 degree Celsius there flow through inside the apparatus and there is an orifice this is your orifice okay. And we want to find out the pressure drooped across the orifice okay. So, what we do we you apply here differential manometer with mercury as a fluid, so this is the differential manometer and what is shown is the density here is given for manometer and the height difference.

So, when you apply this you observe height difference, height difference represent there is a pressure drop. So, the high difference which means this here is given as 200 millimeters, so what is the pressure drop. So, we talked about there that this is let say 1 this is 2 okay. So, P 1 - P 2 is going to be Rho 2 to which is the density of the mercury - Rho 1 which is the density of the gas multiplied by g and h okay. Now in this case density of gas is closed to 1, 1.2 kg per meter cube okay and all. Density of mercury is quite large so we can ignore and consider this to be simply the mercury density multiply by h okay. And that is how we are going to plug in the values and we can get the value which is 25.84 kilopascal.

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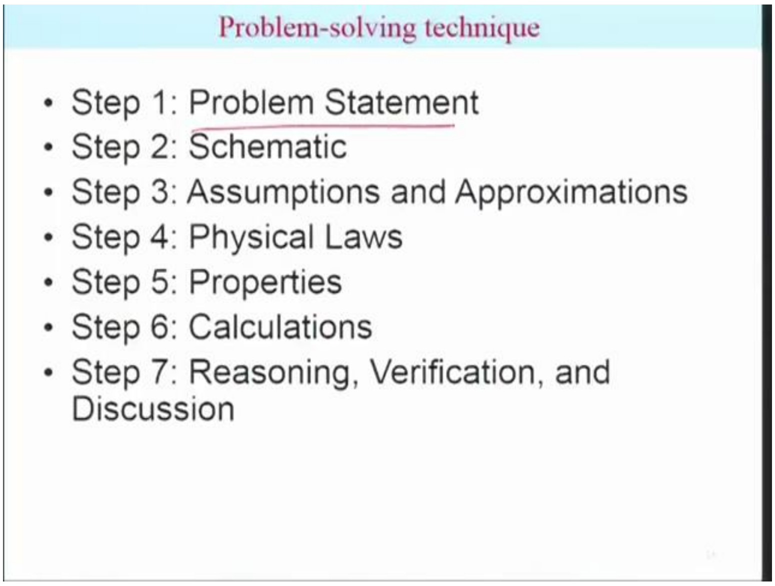

So, in this course we essentially of going to fallow a certain pattern like you have been given a problem and so that would be a problem statement okay. And there has to be a you can come up with the schematic diagram of the problem, which will allow you to solve the program more efficiently that is the schematic will be given or you come up with the schematic, we start with the assumption and approximation just like in the previous example we assume that the density of the air is smaller than the mercury and then we apply the laws, use the properties calculate whatever the values you are desired to do that and provide the reasoning and discussion.

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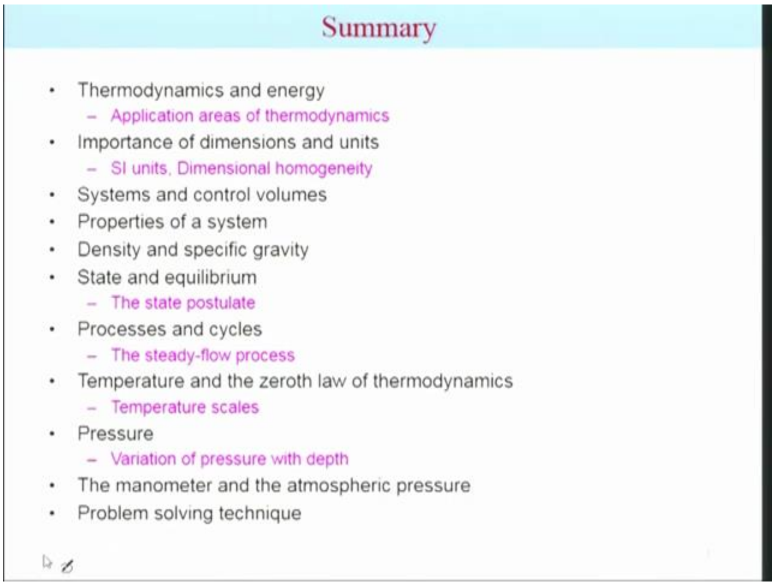

So, this is a format which we will allow to solve any problem more efficiently and illustratively okay. So, with this I think end this lecture I go through the summary again in the when I am going to start the next lecture.