Engineering Thermodynamics
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Week-01
Lecture-3
Temperature Scale and Pressure

Welcome back. Welcome to the third lecture on temperature scale and pressure. Till now we have studied International Standard Units, Systems, State Positive Equilibrium Process, Properties, Process Paths and some specific examples like Gravity and Density. In this lecture we will try to understand about Temperature and Zero Law of Temperature. In fact, this is a recap, meaning we are revising it because we have already read this concept. So, what is the zeroth law of thermodynamics? In the zeroth law of thermodynamics, basically if you take two bodies, like here, iron which is at 150 degrees Celsius and copper, if you join them and stick them together, So, the surface is in contact with the surface. Assume that the surface is isolated. So, the surface is isolated, and the surface is closed from the outside. So, the body will come to a common temperature. When the temperature is the same, we call it thermal equilibrium. Zeroth law says that if two bodies are in equilibrium with the third body, then they will also be in equilibrium. Both are in the thumbnail equilibrium and A, and B It is not necessary that they are connected, still A and C are in thermal equilibrium. Suppose for example, your B is in the middle, and this is your A, and this is your C. If A is also in equilibrium, and B is C, then A and C will also be in equilibrium. Whereas A is not physically in contact. So, zeroth law only says that you basically anybody if suppose for example The temperature is T, which we can measure with a thermometer. and both the body temperatures are same, so essentially, they are at the third body is in thermal equilibrium. This means that as mentioned earlier if the third body which we are talking about suppose B is the third body if we replace the third body with a thermometer then zero is saying that two bodies are in thermal equilibrium if both have that is A and C if A and C are at the same temperature which is B's temperature they will also be in equilibrium whether they are in contact or not. So, this is what it means. The temperature is relative. If something is hot, you say it is hot. If something is too hot, you say it is too hot. So, we need a reference point to tell the temperature. How much is the temperature? Is it more or less? We have water available. This property is reproducible, it means it doesn't change in any particular condition like freezing and boiling point which we call ice point and steam point So what is the definition of ice point? A mixture of ice and water that is in equilibrium with air saturation So when ice is formed, then you have ice that is in equilibrium with water as you can see above, there is liquid water. But since air is also available in the ice point, there will be a vapor in the air and a vapor in the water. So, the definition of the ice point is that the mixture of ice and water means that both ice and water are in equilibrium. And the air that is saturated with water vapor is in equilibrium. and the condition should be in 1 atmosphere and temperature should be 0 degree Celsius so this particular ice point is called reference because water is converted in 1 atmosphere to ice at 0 degree Celsius, so 0 degree is your reference point similarly, steam point is also an important reference point In this, the liquid and water vapor are in equilibrium at 1 atmosphere pressure. At 100 degrees Celsius, steam point is released at 1 atmosphere. Similarly, 0 degrees your mixture of ice water will be equilibrium on this saturated vapor So this is the reference point Apart from this We take a definition that is called thermodynamic temperature scale Normally it depends on your reference point But thermodynamic temperature scale is the scale that does not depend on any property or substance It is independent So, there are two important scales that are relevant for us.

This is the Kelvin scale, which is specifically on the international standard of SI unit. And the same ranking that is used on the English unit is called the ranking scale. The temperature scale that matches Kelvin closely is called the ideal gas temperature scale. The thermodynamic temperature scale is independent of the substance's properties. The pressure of the gas behaves at low pressure The particles of the gas do not interact with each other and the pressure is directly proportional to the constant volume If you measure the pressure of the gas at constant volume and temperature, this is low pressure, the value of pressure is also low. If we are able to measure, if we are changing the temperature and if we are able to measure the pressure at constant volume, then, no matter what type of gas it is, gas A, B, C, D, the slope will be different, because the properties of the gas will be different, but the slope will be different, but eventually, all this, the lower the pressure, the lower the temperature, Merge on your Minus 273.15 And this particular point is called absolute vacuum. Okay, so minus 273.1 degrees Celsius or zero Kelvin. Zero pressure is nothing but an absolute vacuum. And this concept of constant volume gas thermometer or idle gas temperature scale, this depends on low pressure, the principle of low pressure, in which temperature is proportional to pressure at constant volume.

Now, as we said, the temperature scale is a scale that is associated with Celsius. T K is T degree Celsius plus 273.15. And in the corresponding English scale, your ranking is related to the final night. This is the scale. The relationship between your ranking and Kelvin is in this scale. In this course, we will mainly relate to Kelvin and Celsius. scale changes are same. Absolute values are different but when we talk about differences like T2-T1, whether it is in Kelvin or Celsius, it will be same. Similarly, the same concept comes in your ranking. So, this is the comparison of magnitude of different scale. Similarly, the comparison given to you is given in this form, in the form of diagram. Originally, when the Kelvin scale was made, the lowest point was 0. And the reference point is basically Ice point, but after that it changed to triple point which is 273.16 or 0.01 Celsius Okay And this is in the corresponding English scale, so this was about temperature circle.

Now we will talk about pressure. Naturally, I have read that you are recapping the pressure. We will try to understand it through some examples. By definition, pressure is nothing but normal force per unit area. This is your definition. Normal force per unit area is used for gas and liquid. So pressure unit is 1 Newton per meter square and specific unit is Newton per meter square Bar is also written as 1 bar is 10 to the power 5 Pascal and one atmosphere can be used as well as 101325 Pascal or 101.325 kilo Pascal Suppose you take two people with a weight of 68 kg and a weight of 137 kg and suppose the feet are the sole of the shoe and the surface area is this much then you can say that the force is mass into gravity and you feel the force is this much so the force is normal force by unit area 68 multiplied by g divided by 3300 cm2 we will convert this into meter which we can write as Pascal later so this much is left so this is around 2.3 if 22 is proper then 2.3 will come and this is 136 kg person and his pressure is this much Double must double So obviously you can see that if you have more weight than your If you put too much pressure on your pelvis, it will affect your muscles. So, it is important to maintain an ideal weight according to your structure. This simple is shown by mathematics.

Now pressure is also presented in many ways. We use the term absolute pressure, gauge pressure or vacuum pressure. These are the three terms that we use. Absolute pressure is actual pressure is the absolute pressure of any position. The reference of the absolute pressure is always done by vacuum. For example, if this point is to be pressure, the pressure of the vacuum is P absolute is equal to 0. The pressure is almost equal to 0. The pressure is the same as the pressure of the atmosphere. Suppose the pressure of the system is this, which is less than the pressure of the atmosphere, then it becomes absolute pressure. The second pressure is the gauge pressure. The gauge pressure is always different. The gauge pressure is always a difference between the absolute pressure and the local atmospheric pressure. Gauge pressure is the absolute pressure minus P atmosphere. Gauge pressure is the reference of the absolute pressure. When the gauge pressure is zero, it means that the zero is fixed on P atmosphere. So, P gauge 0 stands for P atmosphere. If you are measuring and you are finding out that 0.1 has come out in Pascal, then the actual absolute value will be P gauge plus P atmosphere. So, this is your P gauge. So, P absolute is your system, and its pressure comes out. So, this is the atmosphere. So, what will be a P gauge? This will be the value. and if you want to get P absolute, you have to get this p gauge plus P atmosphere then you will get P absolute third is vacuum pressure vacuum pressure means pressure below atmospheric pressure so suppose for example this is a system and we have to get this pressure as absolute pressure which is less than P atmosphere so what will be P vacuum? P atmosphere minus P absolute that is a P vacuum pressure.

Now pressure varies on the height of the fluid. But if any fluid is resting, then there is no pressure variation horizontally. If it is flowing, then there will be a variation, but when it is resting, then there will be no pressure variation. So if we look at this Suppose the density is rho.

$$\sum F_z = ma_z = 0$$

$$P_1 \Delta x \Delta y - P_2 \Delta x \Delta y - \rho g \Delta x \Delta y \Delta z = 0$$

$$P_1 - P_2 - \rho g \Delta z = 0$$

$$P_2 - P_1 = -\rho g \Delta z$$

$$P_{below} = P_{above} + \rho g \Delta z$$

This amount will be more. Right. And this part is, suppose for example, this is called atmosphere. If this is your liquid, suppose this is the atmosphere. So, the rest of the element, which is going down, is your p gauge. And this the length of the arrow indicates that the amount is increasing as we go. And this will be literally linear form. So, the fluid at rest will increase in depth as the pressure increases as the pressure goes down. As a result, the amount of weight will be added at this point. So, the pressure on the upper part of the weight will be added at the lower point. For example, you have taken a fluid in which P1 is equal to P atmosphere, this is 1. And if you are interested in taking out P2, then you take out P atmosphere which is P1 plus rho g h. I have taken its absolute value. I have not said that minus delta g, delta z is absolute value. So, where did this equation come from? We have balanced the force and that is how it came out. So, this pressure in a liquid at rest increases linearly with distance from the free surface. So, this equation that we have drawn, which you are seeing previously, is increasing linearly as the height increases. And if we take the free surface, if this is the free surface and the P atmosphere is above, then We can also call this P as P gauge because P is P atmosphere plus rho g h so we can also call this P gauge equal to rho g h because this means P minus P atmosphere If there is density variation in the fluid with height then we can also call it differential So if we differentiate it with respect to z, as we did here, this part, you will remember that it was written in the previous slide.

$$\frac{dp}{dz} = -\rho g$$

$$\Delta P = P_2 - P_1 = -\int_1^2 \rho g dz$$

This is only when density is not constant. When it varies. This is a specific way of writing equations. It will be useful for specific examples. This is also important. If there is a single fluid, like water, then there are many contours in it. But what is important is that this level, all the pressure will be same pA should be equal to pB should be equal to pAC you can prove it but here h here the fluid has changed so this pH will not be same as pi this level is same but the fluid is not same if density of fluid is same then density is same so at one level whether it is a container or any other region the pressure will be the same where the fluid density changes then p1 and pi will not be same because this is water and this is mercury so this is an important concept so it can be used quickly The pressure is the same at all points on a horizontal plane in a given fluid regardless of the geometry provided that the points are interconnected by the same fluid. In pressure, Pascal law applies to the confined fluid. It is applicable in quantity. Let's try to understand it through examples. Hydraulic jack is a valuable tool for picking up a car. It is a small device, but it is very valuable. It can lift a small device with such a big weight. And this is how your Pascal log works. To understand this, suppose there are two pistons, one is for a small area and the other is for a large area. We are putting force here. Imagine that you have put a hydraulic jack here. We are putting a small area here and you want to lift the big weight from the second end. force is very much applied in that. So, if you have applied force, then naturally force is nothing, but pressure multiplied by area. So, the area is small, so here is the pressure and the corresponding same fluid is the same density, so P2 will be the same. So P2 is the same and the area, so here if the pressure is same, then the area is naturally different because the area is big. So, because of the pressure, the area increases, the force increases. You applied the specific force, the pressure is the same, but the area is too much, so the force increases. So, the pressure will be the same, so the force per unit area should be the same for both. F2 is applied by the force applied by A2 by A1 So we apply this principle in Pascal's law Area is called the ideal mechanical advantage of the hydraulic lift Pressure is also used a lot in your measurements in which the manometer and atmospheric pressure are measured in the barometer so the simple concept of barometer is that your pressure is measured in the barometer Mercury is used to measure the atmospheric pressure and this is your rho g h simple relation comes out of here Mercury you have kept here and here is the vacuum so here is p0 so naturally the height that it has risen that is your height because it is balanced so the area of the P atmosphere is here and this This P atmosphere will be equal to rho g h Because weight P atmosphere multiplied by A must be equal to rho g h Which is the weight of mercury multiplied by the area of cross section So normally P atmosphere is equal to rho g h So you can multiply the height with density and grams So you get which will be 760 mm what does it mean? if you take mercury from this step then the height will be 760 mm rise at 1 atmosphere 0 Celsius so in this length and cross sectional area is not important because you can see that area cancels and there is no logic of length you can't see any length have no effect on the height of this. It means that if you take a thick tube, or a long tube, or a very thin tube, all three of them, in this condition, one atmosphere, zero degree Celsius, and this is of course mercury, all three will rise at the same height, which is 760 mm Hg. So, this was the concept of manometer.

Now let's come to the manometer. A manometer is used to calculate pressure difference. It calculates small to moderate pressure difference. Usually, we use more than one gas or fluid. This is the design of the basic manometer. Here is one gas and here is another fluid. Naturally, notice that the dash line shows the pressure here. So, if I want to remove the pressure from here, I have to use this particular density. is particular density. I need this head which is called rho g h This particular rho is 1 and the second is that this has to be added at this particular point which is p1 and p1 can be assumed as the pressure of the gas p of g so p can be approximated as p1 so this p of let's say 3 okay if we say 3 here so p3 is equal to P1 because it is going up, so it will be minus rho g h Okay, so. We can do it in other ways also. For example, if P3 is open. So P3 is nothing but atmosphere. So, what will be P2? P2 will be atmosphere plus rho g h. So, this is P2. So, you can also find out the gas pressure. Suppose you don't know the pressure of the gas. So P2 is equal to P atmosphere plus rho g h. This will be P1. And we will approximate P1 as the pressure of the gas. So, this is also an important way of finding out the pressure. pressure using different kinds of fluid. Now in manometer, suppose you use 3 fluids, in which fluid is 1, height is 1, height is 2, height is 3, then you can also remove the pressure of this fluid. It is simple, you have to apply the height of the fluid after the period. So here is rho1gh1. This is your rho2 g2 h2 This is your rho3 g3 h3 Add all three and add the atmosphere Then your pressure will come at 1 So this is a simple concept Similarly, if you take out the differential manometer We want to take out the pressure difference of two particular points And here you notice that there is a tube here Which is irregular geometry and then comes the tube which is a different fluid so this is a different fluid and this is a different fluid this is the fluid which you want to pressure from this point to this point that is in the middle of the tube so this is also a straight forward analysis first you have to understand that P2 that pressure is depending on this and this at this particular height and pressure at A and pressure at B must be same both should be same,

$$P_1 + \rho_1 g(\mathrm{a} + \mathrm{h}) - \rho_2 g\mathrm{h} - \rho_1 g\mathrm{a} = P_2$$

$$P_1 - P_2 = (\rho_2 - \rho_1) g\mathrm{h}$$

So, this is a simple exercise So if you can do these simple exercises Then you can easily Take out the pressure difference So here also we close with an example This particular lecture Here is air Okay

The experimental setup given here Air is flowing in it and we have to extract pressure drop pressure drop across the orifice we have to extract pressure drop in between so we can understand it as basically we have to extract pressure drop between these two points right? and they are saying that the density of mercury is given and the height difference between the two tubes is 200 mm So we have to tell in kilo pascal Now let's assume that this point is Because we know the height difference of this only This one is known in height difference So because the air The air density is very less compared to Mercury So we can approximate that Air pressure from here There is no change because the air density is less If you have So, we will keep it simple that delta P is 1, this is 2, this is 3, this is 4 and this is 5. 1 minus p5 This is your pressure drop. How much pressure has been reduced while flowing. P5 will be less, P1 should be more. We have approximated that P1 is equal to P2. Because the air density is very low. So, this drop is similar. So, this will be same as P3. And what happened to P4? P3 minus rho of mercury G, the high difference given, suppose this is H, then it becomes H. So, and this P4 we approximately as P5 because AI density both coming. So, P1 minus P5 is nothing but is nothing but. P1 is the approximate value of P3 So P5 and P3 This is nothing but P1 and this is P5 So if we rearrange this So we get rho g h here And we get P5 here So P1-P5 is rho Hg g h which is delta p so delta p is simply rho g h in this case and if you put its expression in other things then you have density you have acceleration particularly here so g value is 9.5 msq and height is given so in this you have to change units from millimeter to meter then you can clearly in this unit, kilo pascal so key important thing in this is that I have approximate this that the change in this case is very less than delta p so 1 and 2 and 4 and 5 is similar pressure and simply delta p is your rho g h but if you have this distance also If the height was given, you could have added the density of air but it would have been negligible. Because your rho is 10 to the power 5 times higher than the air. So, your decimal changes too. That too on the decimal after this. So, such an engineering approximation becomes valuable sometimes if you don't have the information. So, this was the last example of this particular lecture. In general, if we want to solve a problem, then first you should have a statement. And according to that statement, you should make a drawing or a schematic. What is your problem, what is the system, define it, what is the surrounding. And after that, the assumption approximation is important. Any problem, like I just took the assumption about air. Which law will you apply, what are the properties, and after that, when all the details come, then you can do the calculation. Finally, when the result comes, it should be reasonable. There should be reasoning, verification and discussion. So, in some sense, these are the 7 steps that will normally be useful in problem solving technique. And we will use them regularly in our course. So, this was the summary of the last 3 lectures. In general, we discussed thermodynamics, the term of power conversion from heat or science of energy transformation. Then we discussed unit, dimensional homogeneity, system, open system, closed system, a steady flow process. Eventually, in this lecture, we talked about temperature and zero flow of thermodynamics and pressure. So, I hope that this has come this time. If you have any questions, please message me. And then, in the next lecture, we will see you again. So, I will see you in the next lecture. Thank you.