Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Engineering Thermodynamics

Lecture – 03
Property of system

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Let us start this lecture just recapitulating what we have discussed in the last lecture. So if you recall that we started with the thermodynamic problem being analyzed by two approaches, one is microscopic approach, other is microscopy right. And then we also looked at various concepts and definitions which are essential to understand the gamut of thermodynamics, because those are the language one has or the word terminologies one has to be, you know keep that in mind.

And we looked at system and surroundings and then system and surrounding together we call it as a universal. I also emphasize giving an example that, what you call it as a surrounding. If you remember that I took a example of a hot tea and then tea cup, and then I told like nearby wherever its property will be changing due to the heat transfer from the hot tea to the surrounding then only that region will consider as a surrounding not very far away.

And later on we moved to the, what you call the properties right if you remember that we looked at whenever system will be interacting with the surrounding then it will be also the properties will be changing of course before that we looked at various kinds of systems right, system can be divided into three categories am I right? One is open system, closed system, and isolated system. The closed system is also known as the control mass system where mass will not be changing during the interaction between the system and surrounding.

However there will be change of or interaction of energy interactions right between the system surrounding. And question arises like how to choose that, when to choose an open system where the mass will be also changing during its interaction, or the system interaction with the

surrounding. I took an example of the geyser what do you use in your winter days for getting hot water baths am I right?

So I mean in that case the water will be entering into the geyser and some water will be going out depending upon whenever you are using right. So therefore, the mass is changing and so also the heat interaction which will be you know taking place between system surroundings. Then I moved into what you call a concept, what you call property, and we talked about properties and then thermodynamic properties.

If you look at thermodynamics properties are different than the other properties of the matter right, and we told ok like the pressure, temperature, volume, internal energy, enthalpy, entropy, these are all thermodynamic properties what we will be dealing with. And wherever there is the interaction between the system and surrounding then one has to look at these properties and the change in property right.

And what we call how we will know whether it is a, you know property or not it may be a characteristic, it maybe a variable, but it is not a property of the system. So for that we told that it should be exact difference here right there we stopped over. If you look at property is very important.

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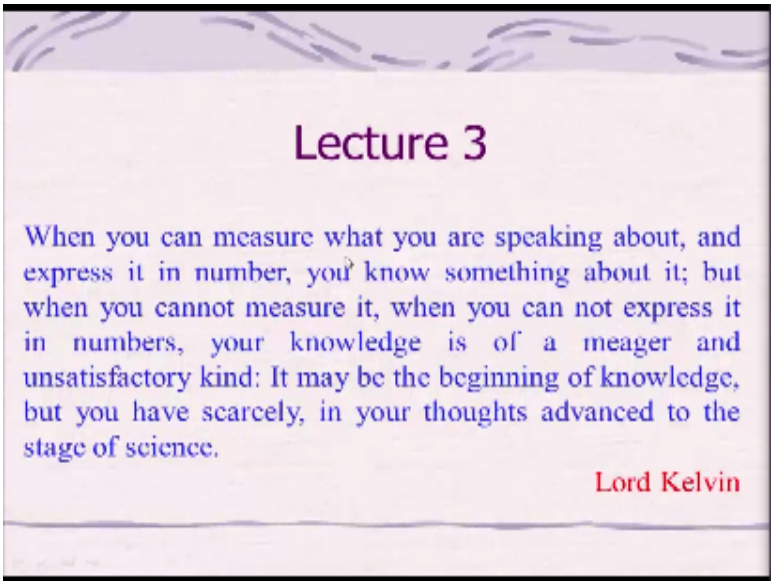

And let me just quote from Lord Kelvin who was told that, “When you can measure what you are speaking about, and express it in number, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind. It may be beginning of knowledge, but you have scarcely, in your thoughts and advanced to the stage of science.

That means whenever you talk about science, the measurement comes into picture and whenever the measurement comes into pictures then, you know you will have to measure the properties of a system right is not it? So therefore it is very important to identify the properties of the system and how it is changing during its interaction with the surrounding.

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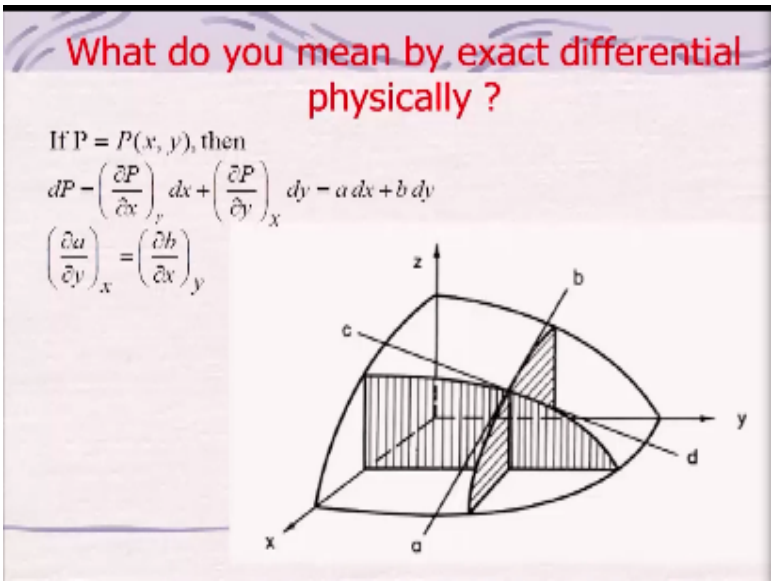

So if you look at what we did, we did basically we took a property is a function of x and y then we looked at dp=δp/δx when y is constant into dx+δp/δy when x is constant into dy=adx+bdy. If you look at what is that a, a is nothing but this term right this term. So, and then these condition has to be satisfied δa/δy when x is constant equal to δb/δx when y is constant, this is a mathematical form.

But if you look at what is the meaning? Meaning is that if you look at X is constant, if X is constant that means what? That means in this plane if you look at this is the plane, and if you take δa/δy right that means change in this how it is happening the slope is here right, that is corresponding to this term. And when I say that Y is constant that means this plane right and δb/δy, sorry δb/δx basically you know it is changing with respect to x direction and this constant so both are in the same point, so therefore it is an exact property.

So this is the, what you call physical interpretation I have shown you so that you can have a field you might have used it, but you may not have that field right, this thing you might have used in your mathematics class right, am I right? So but however, one has to understand what is the meaning of it.

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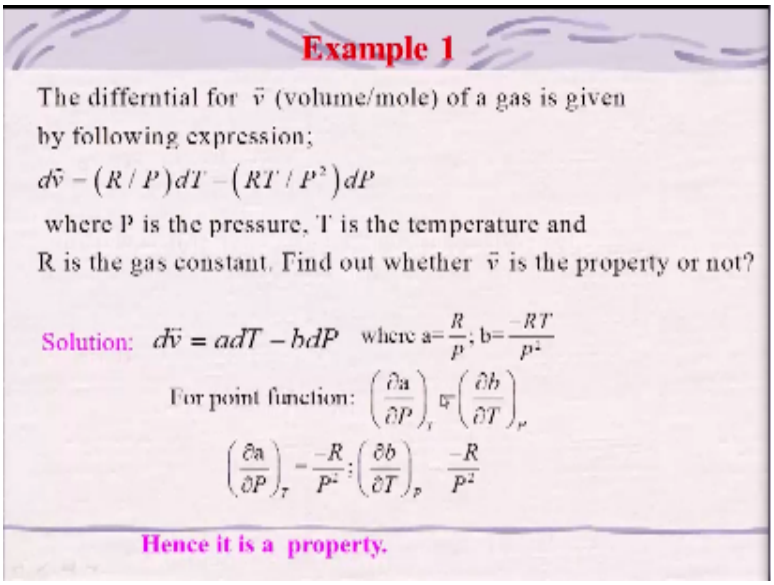

So let us take an example like how we will use this, you know condition to find out whether, you know a variable is a property or not. So let us say that differential for the volume, volume means this is basically a volume per mode right specific volume we can call, of a gas is given by difference by following expression (dv=R/P)dt – RT/P^2)dp, where P is the pressure, and T is the temperature, R is the gas constant, and we will have to find out whether this specific volume is a property or not right of course you might be knowing it is a property.

But we need to know mathematically whether it is right or wrong. So if you look at what we know basically dv=adT-bdP what is a, a is nothing but your R/P am I right? What is b, b=-RT/P^2. So what we need to do, we will have to basically look at whether it is a point function or not and if it is a point function then we call it as a property otherwise no, that means for that to know whether it is a point function or not we have to satisfy this condition δa/δp when temperature remaining constant is equal to δb/δt when pressure remaining constant right, that will have to satisfy from this.

So what we will have to do we know this a, we will have to differentiate with respect to P what it will come it will be –R/P^2 when we differentiate this b term right and δb/δTp is equal to basically –R/P^2, so therefore this condition is satisfied hence it is a property right. So by this one can really understand what is the whether it is a property or not ascertain, whether a variable is a property or not. So let us when we talk about these properties you know thermodynamic properties particularly.

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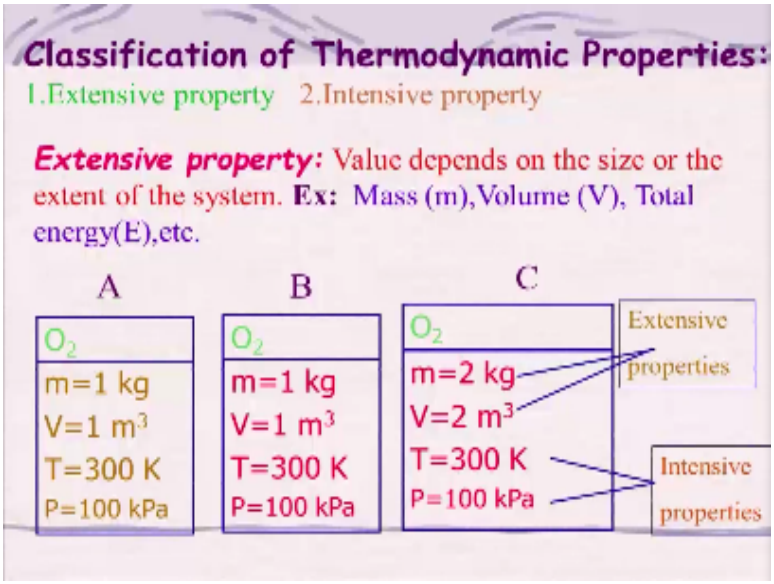

Then we will have to understand what kind of is it properties we it can be broadly classified into two categories, what are those can you people recall one is intensive property, other is extensive property. So what do you mean by the extensive property that means see when you talk about property in a thermodynamic sense it is basically property of the system right, we are not distinguishing in there in the system itself.

So that extensive property will depend upon the extent of the system right that means it depends on the size of the system am I right? So example will be mass, volume, total energy, and other things right. I will take an example which you people might be knowing right, you know that whether this milkman who supplies as the milk in our home right it will be supplying in your, also hostel he is aware about this extensiveness of the property or extensive property, what it does he takes maybe one liter of milk and mix with half a liter of water.

Then it becomes one and a half liter of milky water but he sells it as a milk to you people am I right? Am I right or wrong? That means you know that if I will divide this one and a half liter into one liter and one liter after mixing it will be the, what you call remaining same right or it will be remaining same volume wise, remaining same or not, it would not be is one liter is a half liter. So therefore that property is an extensive property.

Let us take an example let us say there is a cylinder which contains oxygen 1 kg of mass, and 1 meter cube and it is at temperature 300 Kelvin and pressure of 100 kilo Pascal right. And there is

another cylinder B which contains you know same oxygen 1 kg, 1 meter cube and 300 Kelvin and 100 kilo Pascal what is awe allow it to interact with each other. Let us say there is a connector it is connected each other then it became one system right if I call this is as a one system right volume and the another I just joined together or I connect through a tube with valve kind of things let us say.

After that what happens it become like that what will be the volume then, volume will be 2 times of that because $1m^3$ and $1m^3$ $2m^3$ and mass is 2 kg, 1 kg + 1 kg = 2 kg whereas what happens to temperature, temperature is remaining same and so also the pressure right. And these properties which changes with the, you know with addition of these two cylinder, you know and then it becomes extensive property, and the properties which would not change even if you add this you know then that is known as intensive properties right.

So I will give an example right if I take some, you know dhal, you know dhal price is very high nowadays. Let us say hardcore dhal right, you know in the little bit okay. So now I will mix the one is good quality dhal and other is bad quality dhal together right, what will happen the quality will be changing right. Then that quality itself will be which property it will be extensive property, but if I take the same varieties of dhal right, and mix 1 kilo and 1 kilo together it became 2 kilos then what will happen the quality is not changing because the quality is same.

So therefore the quality become the intensive property whereas, you know if you take the kg or the mass will be extensive property right.

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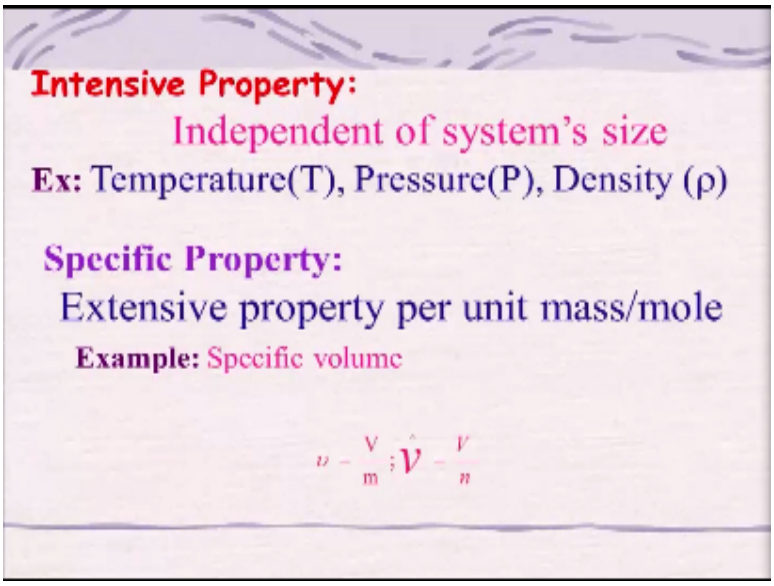

That means how we will know that intensive property is basically independent of system size whatever the size it may be right it will be independent. Generally the pressure, temperature, density these are independent these are the properties which are independent of the system size. So therefore we call it an intensive property and there will be another property which call it specific property.

Just now in the last example we looked at the specific volume, volume per unit mode and the volume per se is a an expensive property, but the specific property which is specific volume for this example like then it is an expensive, it is an intensive property okay, specific property will be basically intensive property. So I mean if you look at a we will be using two term terms one is V, that is volume per unit mass that is if you look at SI unit will be meter cube per kg and there will be V cap some mooke you may find V Bar people use that is V/n that is volume per unit mole right.

And some place you may find volume per meter cube per kilo mole kind of things that you can use. So we will be using both intermittently in this course.

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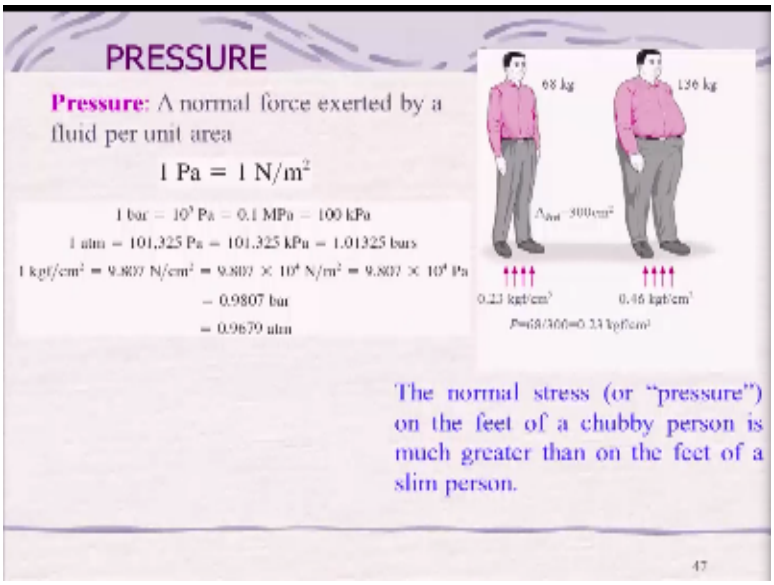

So let us look at pressure, so what do you mean by pressure in a gas or in a fluid either a gas or a liquid we call it pressure basically force per unit area or force exerted by a fluid per unit area, am I right? So if we look at the basically pressure will be, you know force per unit area therefore unit will be 1 or 2 Cal Newton per meter square we call it as a Pascal. So 1 Pascal is equal to Newton per meter square.

And you have a field what is this 1 Pascal means, it is a very, very tiny number tiny pressure right one Pascal is very tiny person why it is so, if you look at one atmospheric pressure is equal to what 101, 325 Pascal right that means 1 Pascal will be what, 1 Pascal will be, you know 101 divided by this, this is very, very small. And of course people, some people call it as a bar, bar basically 1 bar is equal to 10 power 5 Pascal, and you know 10^5 is a big number therefore people use either it has a 0.1 mega Pascal or 100 kilo Pascal.

And similarly one can think of using basically 1 kg a per centimeter square this is M case unit that is equal to 9.807 Newton per centimeter square if you look at this is basically 98.07 kilo Pascal am I right, because 10^3 is kilo so you can multiply 10x9.8 and this is equal to basically 0.98 zero seven bar. If you look at this pressure also in express in terms of PSI pound per square inch right you might have noticed in the some pressure gauge right, you have seen the pressure gauge or some way, or in your anywhere have you seen in some system also we are using mostly SI unit.

But in some industrial application people do use the what you call PS system that is pressure per square inch, one atmosphere pressure will be equal to 14.7 PSI pressure pound per square inch right. So if you look at that is generally in terms of the what you call in case of a fluid that is a gas or a liquid we talk about the pressure right in case of a solid we call it as a what, suppose I am applying a force on a solid per unit area what we call, we call it as a stress right yes or no right.

And let us take an example like there is a person who is, you know we can, was very you know up to mark kind of thing his weight is something 68kg as for the height was fine comfortable and then he is having what we call a feet area of 300cm^2 and the force what will be applying you know duty is weight on the on his on the, where he is standing is basically 0.2kg per cm^2 right. But now he has taken a lot of food and then we came back you know his weight has increased double almost let us say which is not the case generally.

And then, you know it will be basically increasing the weight because is what you call foot area will be remaining same so you can think of using that this thing. So that, you know that pressure was being applied by the same person is become twice of that what it was earlier, because the masses because the mass has increased so gravitational force if you look at you know is the same that is the AMG right.

And then therefore it is having, but here we call is normal stress right we call it as a normal stress because it is applied perpendicular to the area of a chubby person is much greater than one feet of a slim person if it is a slim earlier the person sleep. Nowadays a lot of you know things are going on as to how to reduce the weight and, you know kind of things because our people becoming more fat day by day right what it was not, obesity is increasing like.

And if you look at I just want to draw your attention maybe I will ask your solution, so what happened one, you know small boy is carrying you know a trunk which is having a very tiny handle or a diameter of the handle is very small, but the weight is higher he is getting pain in his hand am I right, because of what, because of pressure right. And now you want to give a solution what you will give any idea any idea like, you know you were an engineer.

So you know the why it is happening he is saying I am getting pen, I need relief you know I remember like when I was a you know keep going to the school we are having carrying a trunk

what you call a box metal box and in that we used to carry the books not like you are nowadays very fancy back which you can hang on the back right. So you know like if it is heavy then you will get and your hand will be you know getting pain and it became a sometimes red color if you were carrying for a longer period of time we used to walk maybe 2, 3 kilometers to go to school right okay.

So it will be, you know like red color kind of things that means the pressure it is being subjected to high. So what is the solution you are thinking of giving any solution see, you know Indians are very good in juga right, but I am not getting anything from you people what is the immediate solution see the what is say suppose you are having handkerchief okay, you use a handkerchief and make it fold it many times whatever possible right what you are doing by that you are basically increasing the area the force is same area you have increased.

So therefore what happens the stress which will be developed on your finger or body whatever it is it will be reduced you relieved am I right. So simple you should apply how it is that is the very important thing similarly an old man is trying to cut with a knife may be a very difficult fruit or something to eat. So he is finding difficulties and how he will you know solve his problems so you think about it will I mean discuss maybe some other time.

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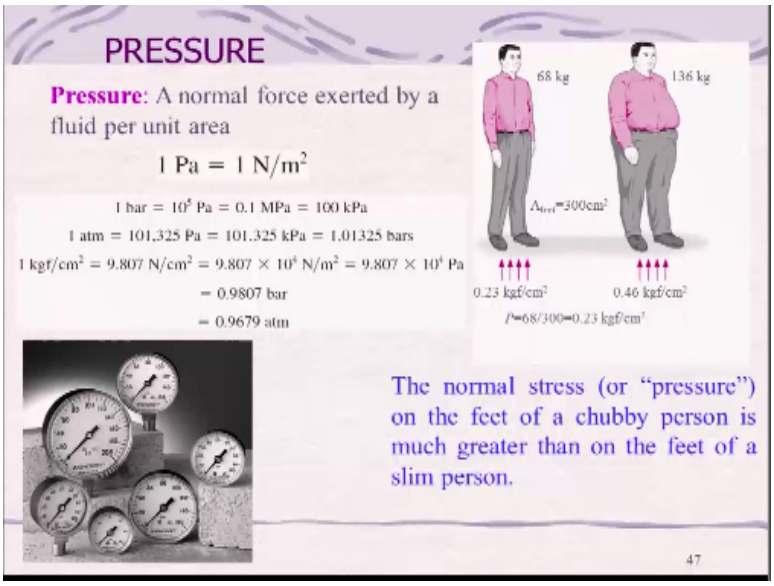

So if you- look at these are the pressure gage what I have shown here right did you see any kind of pressure guess this is a basically pressure is where did you see cycle stand right so how does it work what is this did it you know make you to think and then how it is functioning how it is giving pressure and what kind of pressure it is right so if it is not exciting if you are not you know triggered by that then you know you are not looking it scientifically were just looking like a layman you know so will be now see we will have to define also various kinds of pressure will be handling right to the absolute pressure that is basically the actual pressure at a given position right and it will be basically relative it will be major relative to the absolute zero pressure that we call it as absolute pressure there will be gas pressure right.

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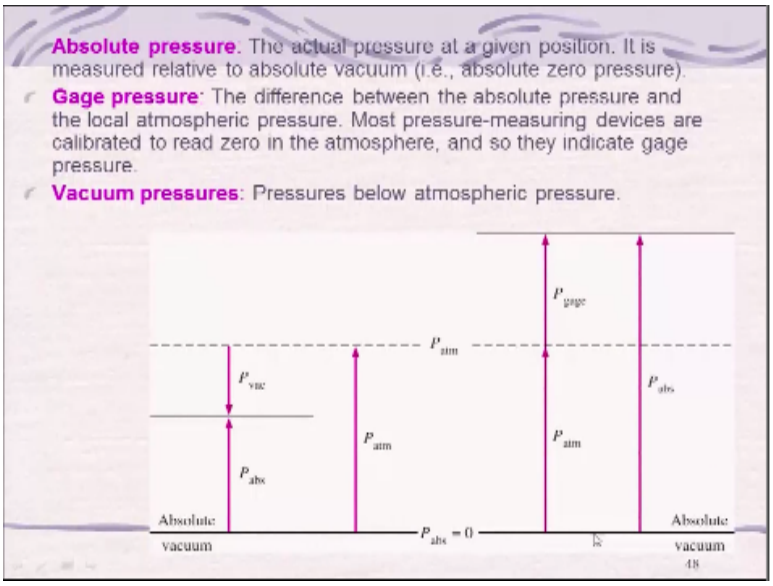

Gage pressure means the difference between the absolute pressure and at local atmospheric pressure will be basically known as the gage pressure and most of the pressure measuring devices like what we use in our day to day life and engineering also that will be measuring the gage pressure right so what the question I asked you that whatever the Gaels you must have used or you might have looked at it particularly when you are giving the pressure or inflating your tire of the cycle or a car I think some of you might be knowing how to you know drive the car and or motorbike right.

So these that pressure all the time the person will be you know giving or feeling your tire pressure he will be checking whether it is proper pressure or not am I right with that there will be a gauge so that will be measuring the gauge pressure and pressure below the atmosphere is basically that vacuum pressure so if you look at this is your absolute vacuum or the P absolute is 0 and then the if I say that pressure is here this is absolute pressure from here to there and atmospheric pressure is this much.

So the gauge pressure will be basically absolute pressure minus the atmospheric pressure what we give the gay phase gage pressure but whereas the vacuum pressure will be atmospheric pressure minus the absolute pressure it will give you the vacuum pressure right so what we will be dealing in this class or in this course that will be basically we will be using the absolute pressure although we will be measuring most of the time what you call the gas pressure now we are discussing about pressure let me ask you a question like you must be feeling very often.

You are inflating your tire the tire of your cycle by second am I right yes and you might be also maybe your parents will be having car and they might be also what you call giving the pressure to their tire kind of see which pressure will be higher which pressure will be lower and what will be the order of pressure can anybody any give that car pressure in the tube of the car will be higher than the cycle pressure or bicycle what we use in our campus or it will be other way around what is your guess high pressure will be higher actually it is not okay you please think about it.

Why it is so how it is so and why this and you will I will tell you the you must not I have looked at your tube or the tire on wherever you were you know changing it you must go and check what is the pressure given there right you will start price to see you must not have noticed any of you have noticed you might have changed your keyword time right yes or no bicycle not change you can throw am I right? But still then you will be changing or you change the cycle nowadays that is the you know that you change you know use and throw but still then you will be changing you just should look at it.

The pressure will be something around what you call may be something 85. 215 psi it will be written in India also we are having the colonial overhang we are still using PFA payable pounds per square inch okay. Now wished suppose the rear wheel is there and the front wheel right so where prices should be higher that is a simple question okay. So you think about this thing so whenever we talk about it we need to measure pressure I told that.

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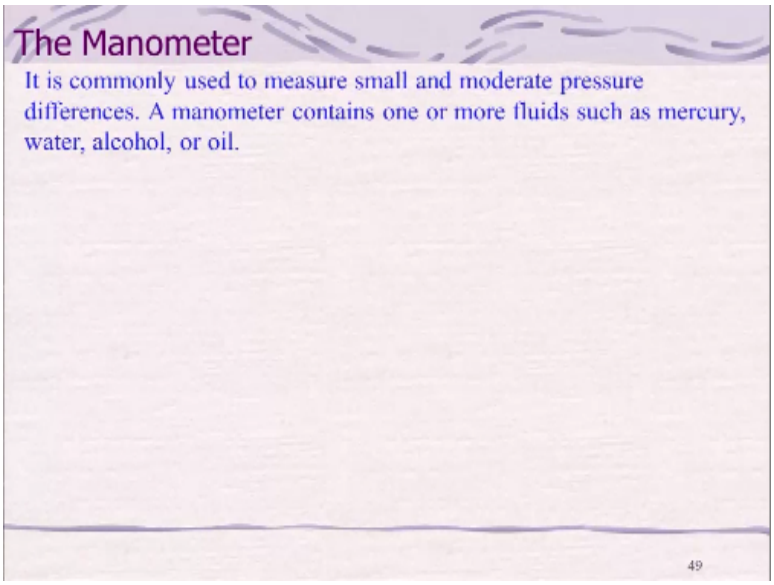

There is a gauge which is being used let us look at that this is a commonly used manometer you might have solved a lot of problems on manometer before during your Jay exam am I right? And it is basically commonly used to measure small to moderate pressure difference like here will be measuring the pressure difference you can think of pressure difference as a gauge pressure you know you can think of or sometimes it will be and most of the some of the manometric fluid are basically water alcohol oil kind of things right and we can also device some these things which will be helpful depending on the situations.

For example questionnaire is a where you will use mercury where you will use water where you will use alcohol and that will be depend on the properties of these trees particularly the density you know like mercury is having what higher density than the water and alcohol will be lower density so also oil as compared to water right so if you consider one atmospheric pressure will be equal to how much of water head any idea if we just calculate it will be something around.

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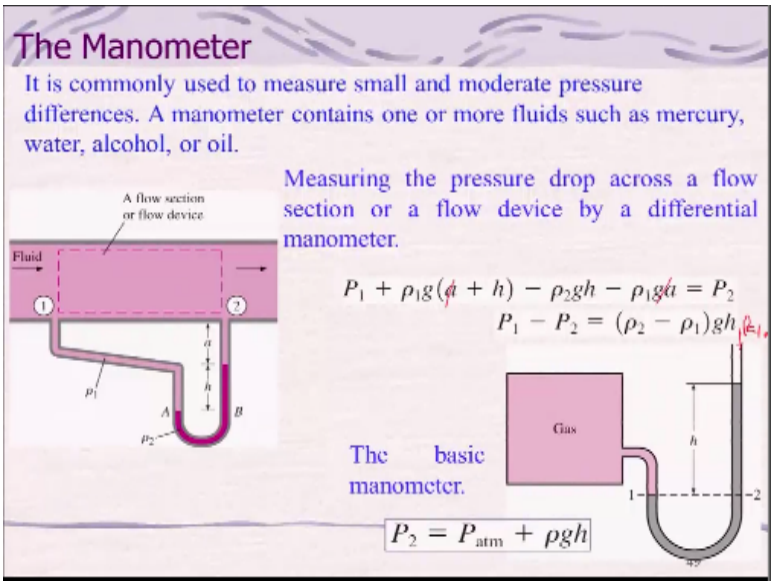

10.3 meters of water health right so let us look at a tank which contains gas at a higher pressure which is connected to a u-tube manometer is just a simple glass tube with a graduation so that you can measure the height and this fluid because of pressure it is pushed these things the this a manometric fluid right and it has this reasonable and you can say that difference between this change you know in the manometric fluid height due to this pressure is H right. So I want to find out connect this H because I can measure this height right and then connect and then calculate the pressure of the tank.

So what I will have to do what I will have to do I can take this is my reference right pressure I can calculate what will be this height of that and then I know the manometric you know through it density right let us say this is the density of the fluid and then I know that this gravitational force is acting right so I know that and what is the pressure what is if some pressure is acting here what pressure it will be acting what pressure will be acting here at this point P atmosphere right so I can say that P atmosphere right so I will do a balance what I will do that p2 is equal to P atmospheric plus ρgh this oppression plus ρgh right it will be changing with respect to height because of you know gravity.

So then I can find out very because I know this atmosphere pressure I know the density of this row is density of what density of manometric fluid and g is your gravity gave the gravitational acceleration right and this gravitational acceleration will be changing with respect to height am I right? Of course manometric in the same is this thing we are considering so H is the height we

can measure now and then this P_2 is same as that of the P so therefore we are saying that tank pressure will be same as that of the P1right.

So now let us look at the measuring the pressure drop across the flow section you know in this device the flow is taking place and we have connected you know with the Station one with a manometers right this is U tube and also there is an incline sometimes people call it inclined manometer as right and I need to measure the pressure between this 0.1 or the station 1 and station 2 right so that is the thing we will have to and if you look at this is the height from here to this is your manometeric fluid and this height is the change in the manometric fluid right and this manometric fluid must be different than that of the flowing fluid.

Let us say if it is the water you know if then it can be mercury or alcohol or some other things right of course it will be difficult to have alcohol so and if it is air you can use here also what right and let us look at will have to calculate see if I look at this pressure P_1 here and then what will be at this point at this point what it will be pressure P_1 + ρ1 ρ1 is the density of the flowing 3G and a + H this is the height a + H at this point so this pressure will be same as that of same as that up here at this point.

And then what is they will have to go to this point that is ρ2 gh this term like and - ρ1 ga so that is the nothing but your P2 so if you look at this ρ1 ga1 can be cancelled it out with this right so therefore P_u p_2 I am sorry P1 - P2 will be nothing but ρ2 - ρ1 gh right so their change in density will be you know taken care and the gh, h of course we know the height and you can find out what will be the what you call change in pressure between this station1 and 2 so what I would like to say that you will be looking at this kind of the what you call pressure you know some kind of manometer and other things.

Will be giving you some problem in your tutorial classes to solve you and also you might have done this kind of things earlier maybe you can recapitulate this so let us look at the other pressure measurements what one can think of course it is not very much.

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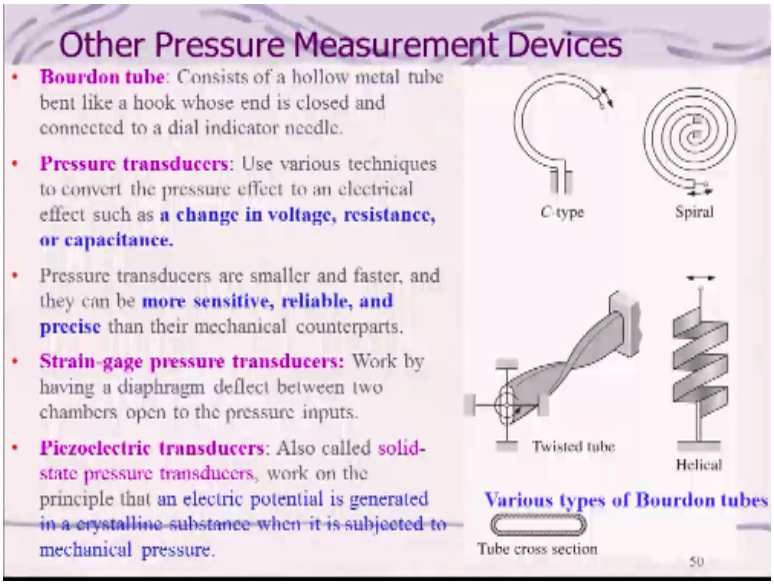

Related to thermo dyne I have given so that you know you can think about something engineering aspect of the gage what I you are you might have seen in your cycle store or maybe car wherever you are inflating your RTO of the car then you know you will be using a Bourdon kind of view which consists of hollow metallic you know tube which is closed at this end right of course there is a various varieties like you know see type spiral type to stay type helical type all are same this comes under the Bourdon gauge or Bourdon tube and what happens when the pressure is.

Let us say it will increase here so what happened to the tube the tube is having a cross section you know of a what you call rectangular cross section or elliptical cross section you can say here it is not a circular you know when the pressure is higher it will be changing and it will be changed changing is position α that it will be inflated and trying to be more circular kind of things and then this will move.

And this point will be connected to your needle there will be gear and pinion arrangement which you can open you can see yourself then that will change because there will be change in that when at the initial condition it will be state that means the pressure is 0 that means with respect to atmosphere and all this atmosphere pressure will be acting here also right so this will be giving you gas pressure and this whenever there is a deflection it will be change into that and it will be so this is the mechanical kind of pressure gauge right which will having certain inertia but it can be used for a very high pressure it can go to very high pressure of course.

There are several -inner to improve its sensitivity there is a spiral type twisted tube and helical type there are several varieties kind of things have people have developed and however in I mean maybe last 70 or 80 years you know he looked honest has come into very big pictures and so that you know people can develop you know change the convert this pressure effect into the electrical effect right such as the change in voltage resistance and capacitance because there is a change in the this thing you can use a diaphragm and then there will be change in that deflection you can convert into the voltage or the resistance or capacitance then you can measure the pressure very easily.

And this pressure of course this is known as transducer pressure transducer kind of things and are smaller and faster right and they are more sensitive reliable and precise than their mechanical counterparts. But however I feel that mechanical one is more reliable and rugged okay whereas the electrical or the electronics kind of things you know in our place where the humidity is very high and the temperature is very high you know those are there life is very small and then you know I always feel the mechanical will be more rugged in our conditions beside this there is a strain gauge pressure transducer work.

By having a diagram and is it deflect between two chamber open to pressure input let us say if it is gas pressure and atmosphere pressure and the input pressure and there is a another kind of things which is being used nowadays very much is the solid-state pressure transducer which works in the principle that you know whenever you press or you apply the pressure then there will be change in the you know crystalline substance and then it will give you the electrical kind of things energy and mechanical pressure.

And that was known as piezoelectric transducer that is being used and it is quite you know it can take a higher amplitude of the pressure and also the larger frequency it can sustain therefore in your IC engine you know IC engine piston cylinder engines what you use in your car there we want to measure pressure will have to piezoelectric kind of transducers so what I would you know like to tell you is that let us say this pressure also is very important this thing if you go that if you go to the higher altitude and if you go to the sea level kind of things let us say you are having the what you call in the sea if you want to get into down what will happen to the pressure.

What kind of pressure will be experiencing right am I right? And if you look at the problem wise it is a quite complicated because the density of the liquid of the water in a sea will be changing

am I right? Because of what salt right is not it so salt will be there the water density will be changing there might be gradient and it might vary and what happens to if you go to the very deep sea of course it is very difficult for man to go to the very deep sea with the modern technology one can go now the g also will be changing the gravitational that wherever we are you know talking about pressure.

G comes into picture am I right? So the g is changing along the altitude and so also the what the sea depth are the you know inside the earth also it goes changing right but the g will be not really changing much right it will be changing something may be 0.1 you know like our kind of one percent of the g average g what we take $9.81 m/p^2$ so along with you know the height it will be changing very less let us say for something for one you know like 1% will be changing maybe 100meters kind of things and therefore we will be taking the constant right but what will happen to the you know the gravitational acceleration.

At the core of the earth any idea you think about it right whether it is changing or whether it will be you know because as you go down the g increases from the sea level to the you know from the sea top label to the downwards towards the arc Center so it will be increasing but what happens at the center as you go up what happens the g will be decreasing am I right? When you go to the higher altitude g will be decreasing am I right or wrong okay, so but the change is not much we would not be considering here and I will stop over here then we will discuss in the next class about the energy and what are the forms of energy and other thing thank you.

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