Engineering Thermodynamics

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Lecture – 09

Thermodynamic Concepts:Pressure. Temperature

Now, look at two important properties, and take some clarifications on that.

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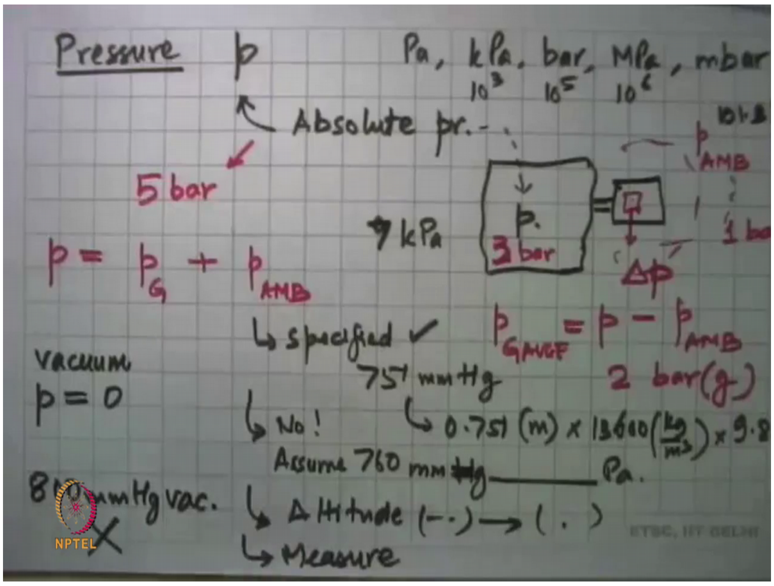

Here, is the first is pressure, here we denote just by the symbol p, and the si units you can say pascal, kilopascal, bar, megapascal. So, this is 10 to the power 3 pascal, 10 to the power 5 pascal, 10 to the power 6 pascal. And everything that you have come across as pressure so far in your life that pressure we always assume implicitly to be an absolute pressure.

But what we measure in real life with any instrument is that here is that instrument, and here is the system connected whose pressure we want to know. Inside this we would have the absolute pressure; outside we have the ambient pressure. And what this instrument will always in measuring and giving a signal or an indication is the difference of these two. So, p inside minus p ambient is what the instrument tells us.

So, when you go to the petrol pump to fill tire air into your tire and that person does it (Refer Time: 02:12) at then shows that this 1.2 kg per square centimeter that is the pressure which is the difference between the actual pressure in the tire, the absolute pressure in the tire minus the ambient pressure. So, what we do is we define this as a gauge pressure. And we say that if the tire pressure, if there was say 2 bar and ambient pressure is say 1 bar or say let say this is 3, then the gauge shows 2 bar.

And to tell somebody what the pressure in the tire was if you say the tire pressure was 2 bar, it means that the absolute pressure in the tire was 2 bar. So, if you want to tell then what the pressure was measured we must always at the symbol g of 2 bar. So, the tire pressure whatever is told to us by the manufacturer, and what we fill up at the wherever we go, we are always saying that what will be indicated by the manufacturer of the tire is of gauge pressure. And what the chap is filling into your tire it also gauge pressure, and that is way the two have working as the same.

And I am talking of the thing about the tire just to tell you that my thermodynamics has its own applications for the car design whether it is a IC engine car or a hybrid car or whatever, the biggest problem for inefficiency in a vehicle is that we do not maintain proper tire pressure, more pressure than what is it is recommended pressure or less pressure than that in, both cases (Refer Time: 04:04) simpler there. And difference can be something like 7 to 10 percent is much more, but here this is gauge pressure and you always like bar gauge. And if it there is more g it always means it is an absolute pressure.

So, if I say 5 bar, it is the 5 bar is an absolute pressure. If a gauge pressure is given, and we want to know the absolute pressure, then you go back here and that that the p is equal to p gauge plus p ambient. And say look I know what is the gauge pressure; how do I know what is the ambient pressure? So, if in the problem it is specified you take that value. So, somebody says the gauge pressure is 751 millimeters of mercury you take that. And to make into an SI unit we multiply this multiply the density of mercury into 9.81, and this will tell us what is the pressure in?

And writing the units everywhere, because quit often you will see getting mixed up. So, somewhere people report Pascal, somewhere people report milli bar, somewhere we work with mega Pascal in units have to be taken take care of (Refer Time: 05:53). So, if it is specified, we calculate Pascal added that is done. If nothing is given, no information, we assume that the ambient pressure is 760 millimeters of mercury. And then we do a same calculation and see how many Pascal that in.

And in some cases if you are told what is the altitude at which it is working, then you can find out that at that altitude what is the pressure, say for instance you go to an 7000 meters above mean sea level, the ambient pressure is almost half bar and that is why we say that breathing becomes a big problem because of lack of oxygen, so we go there and get this value. And in the real world, the best thing is measuring.

A very simple measurement, these there many instruments are there measure it and see what is the ambient pressure and use that in the calculation. So, this is one aspect of this. The second thing that could happen with pressure is if this pressure instead of being 3 bar, it could have been say 7 kilo Pascal. When I say 7 Kilo Pascal that is an absolute pressure. And we know that ambient pressure if I take 760 millimeters of mercury, it is 101.3 Kilo Pascal. So, the gauge that is there at the petrol pump cannot measure this pressure. You need another instrument which can pickup pressures below atmospheric pressure.

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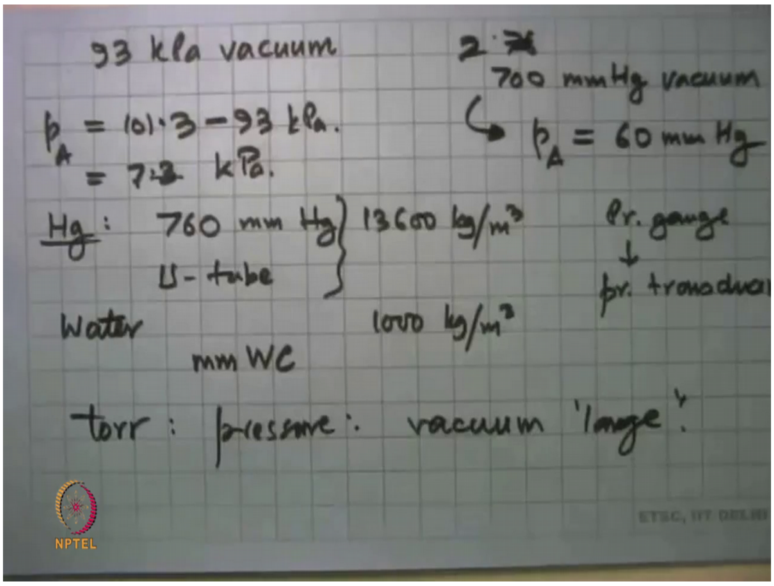

93 kPa vacuum

2·7

700 mm Hg vacuum

$p_A = 101{\cdot}3 - 93$ kPa.

$= 7{\cdot}3$ kPa.

$\hookrightarrow p_A = 60$ mm Hg

Hg: 760 mm Hg } 13600 kg/m³

U-tube

Water 1000 kg/m³

mm WC

Pr. gauge

↓

pr. transdu

torr: pressure: vacuum 'large'.

And when we read that gauge, you will get a pressure, and in this case it will show 93 kpa, but that is the gauge pressure, and instead of writing g we will write the word vacuum afterward. So, this is 93 kpa vacuum or we can say this is say and take 13 760 instead of 760, they say about 76 (Refer Time: 08:32) 700 millimeters of mercury vacuum.

So, this is equivalent t to saying that the absolute pressure is 60 mm H g, 93 kpa vacuum we assume ambient to be 101.32, then the absolute pressure will be 101.3 minus 93 so much kpa. So, whatever number comes the units of that is only kilo pascal. Or in this case it is 7.3, so that is it. And this is important because there are many applications where we come across that process. And we exploit it quite extensively. So, we are going to take care in differentiating between absolute pressure and gauge pressure, and correctly interpreting it has to what it is. So, if that that is the issue with pressure and we will now, look at the other important property that now which is temperatures.

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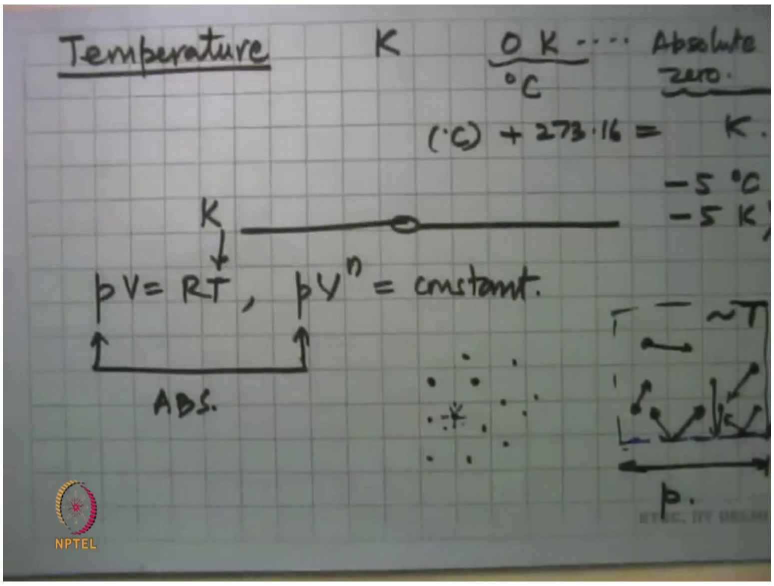

We will come back to it when we look at the laws of thermodynamics. For now we will only say that the SI system that temperature scale will in Kelvin, 0 Kelvin state that has not been never achieved in the state where there is maximum order in the molecules, and anything as you go above temperature the molecule begin to add more energy and that energy is occupied for each molecule by its temperature ok.

So, we start from there and there is no upper limit from Kelvin, practically we will use degree Celsius and you all know what is the relation between these two that a temperature in degree Celsius plus 2773.16 tells you the temperature in Kelvin. We will come back to it when we look at the laws of thermodynamics in more detail. So, now, if this is go to now and the reason I have brought it up here is that you already come across these thing in school and in some of your other courses. And many of you have use equation like pv is equal to RT. And say p v to the power n is constant and things like that. We have not yet started discussion on this, it will come later on.

But the point to note here is that this pressure, this pressure, these are always absolute pressures and not gauge pressures. And in equations like this, this is always Kelvin; whereas, we want to keep that in mind when we are looking at all the other things that we will come up in the later modules and in solving problems. So, that is what I wanted to cover about pressure and temperature.

And one more thing and then we will only take questions; we have time for it all right. I will just cover this part; then, I will come back to questions. We started the first in the first lecture which we defined what was heat and what is work. And we said that when a system and this is surroundings, if heat transfer takes place from surroundings to the system only because of a temperature difference across the system boundary, this is heat.

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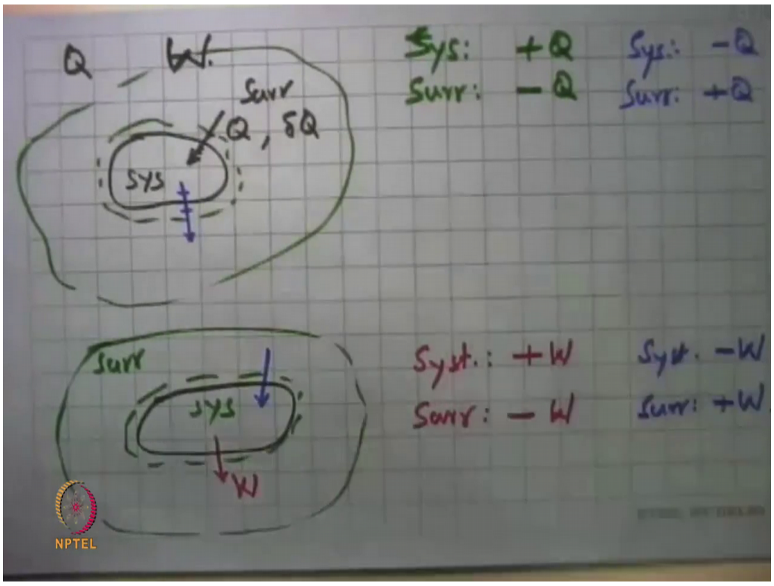

What we did not talk about is what happens to a surroundings. So, we will complete that by saying that if I known only look at the surroundings, so heat transferred to the system from the systems perspective which is what we are trying to analyze for the system this is plus Q. Now, we remove the system, and say about this is the surroundings and energy transfer took place out of the surroundings. And we say that for such surroundings, this is minus Q. So, this definition always goes together that what happens to the system, the opposite happens in surroundings. And in case it is other way around that the system transfers heat to the surroundings that means, the system here is at higher temperature than the surroundings there.

Then in this case system, we say that this is minus Q; and for surroundings this is plus Q. And we can extend that argument to work also, and say that that is the system and we have the surrounding around it, and heat it this as the system bound this is the system boundary. Then if this temperature, if this system does work on the surroundings, then from a system perspective, we said that this is plus W; and as we just saw there from the surroundings this will be minus W ok. So, that is the surroundings and same W which was there for the system as plus W with minus W for the surroundings.

And if you look at the opposite thing, if the surroundings do work on the system, then for the system, this is minus W; and for the surrounding this is plus W. So, say that is it. You are going to remember it we will come up come back again when we look at the second law of thermodynamics. The thing is that I mean define this in the context or system and surrounding the effect of on the system will be opposite of the effect on that is another thing that I wanted to cover ok.

So, let us we will take some questions ok. So, the question here is what do we mean absolute zero reference for temperature scale? When we say that th temperature is 0 kelvin this is what we call as absolute zero. And it means there can be more temperature less than this ok. This is the lowest possible temperature possible minus 5 degree celsius is possible, minus 5 kelvin not possible ok, so that is the meaning of absolute zero.

And if I take a corollary, and look at pressure, and we ask is there something called absolute pressure or the pressure zero. Well, if there is nothing in the system gas or liquid, there is no pressure. So, you can say that then there is vacuum. And technically this means that p is 0 ok. So, there can be no pressure like say 800 millimeters mercury vacuum such a thing does not exist. You cannot go below 760 millimeters of mercury ok.

The next the question here is why we measure pressure in terms of mercury, this is not necessary that you always measure the pressure. The question is why do we always measure pressure in terms of mercury, not necessary, we could use any fluid. Historically mercury is the one that has been coming along. Water absolutely fine we could use water, but water has the couple of problems.

So, mercury what happens why it is so convenient is that ambient pressure is 760 mm. And so if we want to measure pressures below atmospheric pressure very simple thing works. And to make a pressures above thing above atmospheric pressure, we can use the device like U-tube manometer. And so pressures which are like a few up to (Refer Time: 18:01) meter or so, the manometer height will not too long, so that is possible. The pressures more than that we then cannot use U-tube manometers, and then expressing pressure in terms of millimeters of mercury is not convenient at all, so that is there.

We could use water and we often use water because now with density here been 13600 kg per meter cube, water being 1000 kg per meter cube. For the same height of mercury the manometers will measure larger pressure than water. So, if I want to measure smaller changes of pressure, water is the preferred fluid not mercury. So, if I have pressure difference of 100 millimeters of water, then mercury will very very small increase in the level, we are not using the possible to measure it. So, there are takes places when we do measure water. Water has the problematic evaporates, but something needs to worry about and take care of it. Mercury does not have the problem, it has the problem that with the toxic materials.

So, sometimes we do measure and express pressure in millimeters of water column mm WC. Quite often it is done and things like a building air conditioning where the building it is the strictly higher pressure than the surrounding pressure that pressure difference cannot be measured in millimeters of mercury, therefore the thing is millimeters of water column or say a millibar. And in many most applications we do not able to use either of them we use as we use to use a pressure gauge, it is still there, but gradually this is giving way now and we have almost completely move to pressure transducers.

Pressure transducer is nothing but a diaphragm which experiences ambient pressure on one side and the applied pressure on the other side and because of its reflection it generates an electrical signal or a potential difference that is measured it is calibrated and that is taken as the a pressure. And of course, this is all electronic. Can we apply laws of thermodynamics to vacuum, where you cannot we need to define a system and say then what is it doing.

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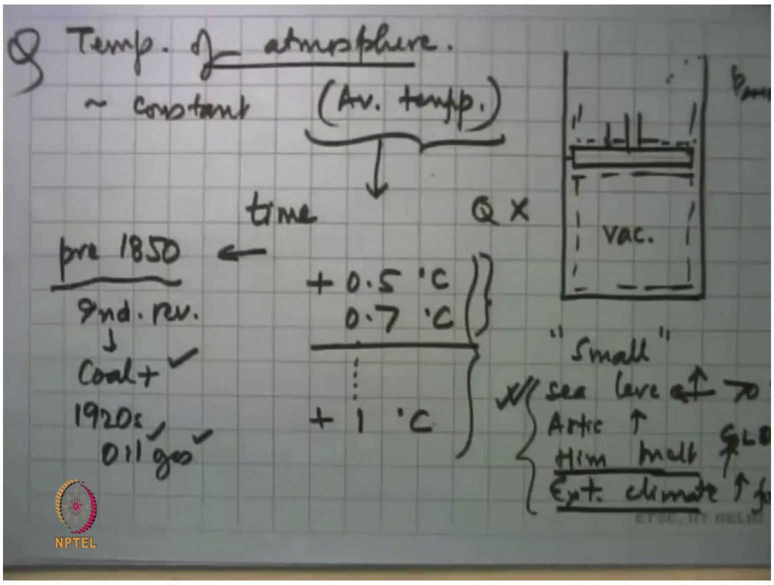

So, the question I will try to create a question out of that. And say that here is there are the chambers which is vacuum in it, this is in vacuum, this is nothing in it. And outside we say ambient pressure. And we try to we have to hold the thing in place, otherwise it will go down that if you let it go, there is a force fating here, there is no force from this side, this is un restrained movement is of go down and completely sit blank on the bottom.

There is no work associated with this we did not have a process, because it did not have a substance over here. Only thing we can look at is what happens to a surroundings or the work done to be on the system as you go, and see that look what is in that the system this surrounding experienced, but vacuum there is nothing there cannot be move heat transfer to it, and this case have you seen there is no work associated with it. So, there is nothing that will happen with vacuum. Using microscopic thermodynamics, how do we define temperature?

So, we go back to the idea define temperatures. And at the microscopic level what is happening is this in solid; we have all these atoms or molecules arranged in certain way. Intermolecular forces are quiet strong, but each one of these is vibrating and oscillating around its mean position. So, in a solid there must the atoms of molecules are not stationary, they are vibrating.

And the energy associated with that vibration or rotation is what we assign it has a number of related to temperature. Then we heat if the molecule takes more energy and it begins to oscillate faster, so that is what tells us that the temperature has increased. In gasses and fluids, then all the molecule are moving around in a random way. Each molecule itself has got its energy, and at if the energy then how much energy it has, it directly proportional to its temperature.

So, we more the energy in the molecule the greater the temperature it will have. So, in the microscopic level these are very tightly connected. At the microscopic level what we do, instead of worrying what each one of them is doing, we take all of them take their average, and check this is the temperature of this material. The same thing we do with gases, and that from the kinetic theory of gas is teaching us. But, again at zero kelvin, there will be no energy in the molecules or in the atoms and so energy becomes zero, and after that nothing can be done.

You take a minute to tell you what is the counter part of this for pressure in solids pressure is not defined, we define in this process so we will leave it away. For fluids, we define pressure. And what we do there with that these are the molecules which are in motion randomly. And we say that if I take a surface there, and say were how many molecules are heating it say if it is in the solid surface, this molecule moved heat it bounced off, let us assume it is perfectly elastic collision.

Another molecules comes from there heats it bounces off, another comes from there bounces off. If each one of these, there is a change of momentum, and so we do not talk about how much (Refer Time: 24:45) as far as the molecule goes its momentum change, because it is velocity vector has changed that what happened to this surface, it experienced a force.

And from it take a largest enough surface that means, this dimension is big enough that there are millions of molecules setting it, and then we take a two dimensional thing again in the same side. And then we say how many molecules are heating it, and bouncing off. And from there we do the momentum change analysis and define pressure. So, this is the hydro stat the thermodynamics definition of pressure.

So, for we do not associate pressure with every molecule, but we do associate temperature with every molecule, and to get the microscopic property of pressure we need to define a system big enough that there are very large number of molecules in it, and that is how we can then define what is pressure ok. This the question here which is in most of the cases, we are taking internal energy as function of temperature in what about pressure instead ok. I have not even touched internal energy yet. Next module, we will start talking about internal energy, and whether it depends on pressure or temperature will come in the module after ok. So, we will we can leave it for this time (Refer Time: 26:01).

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The next question is what are the limitations of using nitrogen, oxygen, fuel cells in automobiles ok. So, you first the question is or the picture that I showed was about vehicle with the fuel cell in it, and what we have done in that whether it was a ok, so that this are difference. Hey I am not too worried about the automobile.

But, I have taken the example of the bus where the (Refer Time: 26:37) if rather than automobile powered by a petrol engine, diesel engine or a CNG engine or the hybrid, which is partly by a battery, and partly by a combustion engine or by a fuel cell the fact is that the more cars you put on the road the more you will see what you see on the roads with the (Refer Time: 26:55) traffic jams that is all you ignore by ignore (Refer Time: 27:00), you look at the example of a bus. And this you can get 40, 50 people going it takes much less road space much smaller carbon footprint even when you look at the diesel bus from the CNG bus, and after the many other benefits for their health issue take for with last problem (Refer Time: 27:17)

But, coming back to the question what are the limitations on this. Thermodynamics as far as it goes with more be worried, and can I get enough energy right enough power for driving this vehicle, whether it is this or whether it is the car or whether it is the truck or whether it is the crane does not matter.

So, if I make a system which is very very big, and way setting terms and you say look yes I have get the power, but as for as the quotation application goes I (Refer Time:27:51) this was (Refer Time: 27:54). So, can you reduce the weight and can you reduce the size, so that is the particle thing thermodynamics still guiding you what is possible and what is not possible, but it does not tell you exactly what will be the size of it. You need to go back to engineering, and select how can I make the size smaller and smaller, and yet we always be constraint by the thermodynamics you cannot escape from that.

And so if you can make it that is what research have been going on for the last like 20 years, and finally made a fuel cell with as you see in this case. The fuel cell seen to be setting with top of the box, it was added the at most height to this vehicle, in that you have also put the hydrogen cylinder, what it takes oxygen from the air, and that is what we got from the top of the bus under that (Refer Time: 28:36) that is the art of engineering, which is the science of the possible that would engineering.

And said once you get that ancient (Refer Time: 28:46) how much does it break and so (Refer Time: 28:48) big about over 150 kilo grams that is what this about weight of as repeated that is ok, it is carrying 60 degree per the operate two three are (Refer Time: 28:57) that were there we can do (Refer Time: 28:58).

So, back to next consideration size, and the weight, and then on one charging how many kilometers will be is this vehicle go. So, then you decide the how much hydrogen (Refer Time: 29:09) heat was stored in is that confused hydrogen. So, fast that after every 100 kilometers, and we need to recharge it is not a very nice thing to have, and that is the reason what the hydrogen powered combustion engine is not a very great thing, but hydrogen based fuel cell is a big advantage over that. So, saying that I can own hydrogen inside thermodynamics region nice to do project, but practically it will be useless, so that is the other thing that you get as a benefits here.

So, and where do you locate it, the automobile that happened we are able to pack all of that fuel cell, and hydrogen hydrate in the trunk or in the front hood, and then we are able to get the electricity. The next part of possibility of making it was power electronics by which you can convert that DC supply into something else control it, and then drive an electric motor this powers the vehicle.

So, there you need to go work on electrical engineering devices machines and make the control system faster. So, those are the challenges that decide how and when and if, these will become finally commercial reality. Fuel cell has several of technical problems and challenges still above call it a problem it is a negative connotation, you can take it as a challenge, then how do I make it, how do I keep it to clean, how do I give it clean fuel all of that is there.

And the biggest thing is that you have to conveyance everybody (Refer Time: 30:34) that you have to hydrogen cylinder on a vehicle or you know car is it safe. And you need to look at all types of possibilities that can happen from this to this vehicle (Refer Time: 30:44), and this gets to an accident then what happens. If this pipe breaks, then what happens; if the fuel cell crakes, then what happens? All of that chosen to make a technology successful ok, so that was the fuel cell question.

What is the significance of entropy into the great circle of sciences ok? We will talk a lot about entropy in the next module, then second law comes in. And we will have work it talk about it, where will the application of the unit torr will use ok. So, the question is torr torr is the unit of pressure, and people use it where we are always dealing with vacuum very large vacuums, where millimeters of mercury millimeters of water are no use, but your vacuum much smaller than that then we use the unit term. And any device in which you have made a vacuum that is what you will do ok.

So, for example you should have been material processing, and you need a very clean environment, then you say that I will measure the pressure of that vessel in torr. So, it is purely a convenience thing using a bar or a Pascal or a mega Pascal is fine, but every time you take somebody about the pressure is you will have to say you know it is this much into 10 to the power 4 Pascal or 10 to the power 6 Pascal that does not help in communication.

So, we will (Refer Time: 32:15) torr how density and humidity are related to temperature, there is the question here ok. I am not going to pick it up right now, we will come back it when you look at the properties of a substance, because we have not yet considered. Now, what is the mixture, and how do I get the properties of the substance when you look at that, then we will look at this issue. So, I keep that in mind. The question of using microscopic approach of thermodynamics how to be different temperature, I just answer that.

Student: (Refer Time: 32:52).

If the temperature of atmosphere is constant, then why we face problems of global warming ok, and so here that interesting question. So, when we talked about temperature of the atmosphere, what we are saying is that is yes for all particular purposes, we are saying that this is constant, it not even constant, but what it (Refer Time: 33:31) then I say this.

This is some sort of a average temperature at many locations over a long period of time that is the average temperature of the atmosphere. So, it is not at a particular location or anything like that. But, when you talk of global warming, what we are saying is that ok. I will look at the average temperature of the atmosphere not at temperature at in this room or somewhere else.

And look at this and how it has changed with time, and what we now have evidence for is that the average temperature of the atmosphere at increased by above between 0.5 and 0.7 degree Celsius. And predictions are that mean is 20 years this increase. So, this increase is 1 degree Celsius. And what is the base the base is pre 1850 average temperature, because that is when the industrial revolution began under the first time this started exploiting coal first in a very big way.

And then early 1920s you started exploiting oil and gas, and that is what started adding per minutes you took the atmosphere. So, as well as your only that means, the rate of additional carbon dioxide to that possible relatively slow means, oil came along with spite up and started increasing relatively fast.

So, this temperature increase which is happening, and is going to happen. We think that this is small and by engineering the things there yes half degree change, it may not be very significant, but then please remember that even a body temperature and my body temperature, when we have fever or temperature of the body goes up only half of one degree Celsius, and that is not enough 2 degree Celsius increase in our body temperature, and we are pretty sick you can get big fever.

So, it is not a small thing just the relative of what is small, and what is large is relative to something else. What is this relative two is what it does to the overall energy balance of the atmosphere, and what are its implications? If the implications were not there, we shall look forget about it let it happen no big deal.

But, there were you say that the sea level is raising, that the artic caps is melting, Himalayan glaciers are melting, a streams of climates have gone up more frequent droughts, more randomly more intense, more frequent floods, more randomly, more intense more frequent cyclones, more frequent hurricanes. When we check evidence of all of this, we can still say look I cannot be bothered. It has to happens happen I am giving on my side everything is with me what is a big deal, only thing is it may not effect some people, but they will definitely effect lot of people for instant sea level raise will effect 70 percent of the population of the world.

And if your house is going to get sub merge, what you do, you going to somebody elses place. In that person you will like it, and you have no problem. If droughts and flood become common, your food is in issue you have a big problem with food. When you get the food from plus there is the damage that things do like the Himalaya.

In the Himalaya you have gloss global glacial lake outwards flood, which is what happened that the [FL] string in few years back that is going to become more frequent, so that is what is go to be worried worrying us. And mark whether this is half degree, one degree or point 0.75 degree, it is this implications which is why that small change in the average or its temperature should be a cause of all of us to worry about ok.

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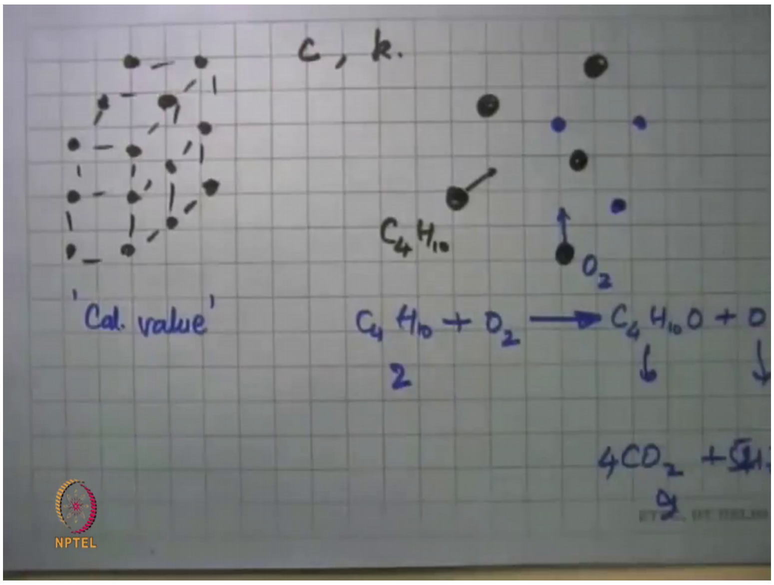

Here is one example that we know that a particular material say aluminium has all its atoms arranged in a particular way ok, so in a 3D matrix. So, this is all the atom. And I say I want you to calculate and tell me from microscopic approach, what is the specific heat of aluminium. All the data we have is measured or it say well tell me what the electrical conductivity of aluminum. And say I know that in the microscopic approach what each these atoms is doing how they are connected to one another, I can write that equation for finding out what is the motion of this, and this, this, this, I will stimulate you know write the mathematics and draw the computer code to do all that calculation.

So, you need a some sort of at least the small mini super computer, a few days to work on it and it will be give you the answer. And you will tell you that specific heat of aluminum is this much, and the thermal conductivity of aluminum is this much that is the type of computing effort it takes do a very simple calculation which is a calculation of this thing. Or if you want to say that if I increase the temperature of these by 5 degree Celsius, what will be the temperature change in the next 100 atoms, it will take that much time to do that calculation. We do not have that much luxury at the engineering level. Now, yes if you are looking at very small levels and trying to answer these questions that is what people do. So, there are people looking at these questions, and trying to answer this ok.

Let us take a second question of a chemical reaction is a molecule say of butane C 4 h 10 your LPG gas and another molecule was air say oxygen. And like this there are many oxygen molecules becoming around, and there are many of butane. And you have to calculate when the rate at which the reaction will take place, and how much energy will be given up. We have from school days knowledge that I if it this complete let me taking place, and the products come back to those ambient temperature in so much energy is given out and that is what we have learned as say a calorific value and we got numbers from that that is all at a macroscopic level.

And when you do that the microscopic level, we can theoretically say no (Refer Time: 40:45) stimulate each and every molecule the way it is moving, I will stimulate the collagen of two of them and see whether there will be some reaction is so what reaction will be there. So, what happens is that by two molecules hit each other there is a probability of a reaction, so that will hit so that means, C 4 H 10 one molecule has come it had heat one o two molecule and it does not straight away become the reactance. It may become something like C 5 H 10 O plus O, there are probability that three molecules will heat at the same time is particular zero,all reactions will happen only by two molecules in each other.

Then this will heat something else this will heat something else like that there might be several hundred such reactions taking place. And finally, we will write CO 2 plus whatever if the number of that H 2 O that is there, so CO 2 and 5 H 2 O. So, here you got 4 plus 5 - 9 molecules this started off with two molecules and every heating with the two molecule process. So, we can calculate all of this we research as in combustion and pollution do make such calculations. You come here we do that lot of valuable inside into what will happening that then we try to make it so in a usable form that the designer of a combustor or burner can use that knowledge. But it takes several super computer several days of a calculation to give the answer for this.

So, yes, microscopic approach is possible it is done it is very time intensive, resource intensive, and as a engineering thing we it does not help us too much. Please give us an example of heat transfers from sink to source ok, I just gave that example, but I will repeat it now.

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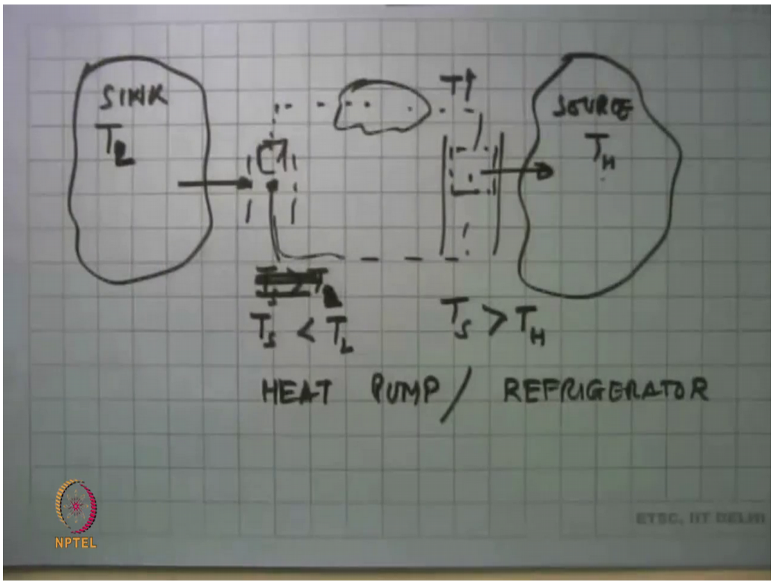

If I have energy transfer from sink to source it will not happen by itself ok. So, here there is a sink; here there is a source. And this is at a higher temperature; this at a lower temperature. You know just to the metal rod between them or any martial between them there will be heat transfer happening we know that. Now, I want to make the opposite happen what do I do, this can exchange heat only with a system this temperature here is greater than T H, so that the system temperature at this point has to be sorry this is T L is more than sorry less than T L. That means, the temperature here has to be less than this temperature. Then heat will come here.

Then this substance is now already at a lower temperature it cannot give its heat there. If it through it into this at the end of a heat, you cannot do it a second time. But if I want to do on continues bases, we then have to put it to a compressor, its temperature goes up or you can heat it and raise its temperature. Now, to make it move you still need a pump or a compressor.

So, you do something to it in this where its temperature has now gone up. So, when this is moving here, here the system has a temperature which is more than the source temperature T H and now heat transfer is possible over here. Then we do something else and bring it back and that is the idea of what we call a heat pump. Its job is to take energy from a lower temperature to a high temperature and it is exactly the reverse of a refrigerator.

So, one can argue that in winter if I consume a certain amount of electricity to keep my room warm, then if I use the air conditioner in reverse with the same amount of electricity, I can make the room even warmer that is possible. These days you are now beginning to see those things type of device is being marketed where they say that this is a in summer you can use it is an air conditioner and in winter you do a switch assume a knobs here and there, and it will act like a heat pump, and you can use it as the heater inventor. So, those devices are the there in the (Refer Time: 45:21) ok, so that is the does at high temperature H 2 O to fuel cell may have a chance of exposure.

Now, here we are a question that if the hydrogen oxygen fuel cell, we will run at a high temperature is there a probability of a explosive. Mostly the hydrogen oxygen fuel cells are being written at lower temperatures, there are some which are run at high temperatures, but then you have to design it, so that first it does not (Refer Time: 45:52) if you are able to do term of the management of that. And yes there is always our remote chance that you can explore must like you should asks the question now a travelling in a aero plane is it possible that the engine will catch fire. And yes there is a finite of (Refer Time: 46:07) fire.

But then that is what engineering is about and we have to anticipated try to see as much as possible and yet there more still be an accident and we learn from it. And the next generation of that machine becomes more safe, and that is why aero planes, aero engines cars they are so much more safer than what they work earlier that is there.

We will go to next question. What is entropy and how it is related to energy ok. This is the question for our next module. I will definitely come back to that place. Let me cover that do not worry. In an isolated system if there is friction in the heat lose due to of friction cannot escape so can that be compared as the reversible process though there is friction. Well there is a answer is whenever there is friction and you have is (Refer Time: 47:12, where in the friction. What is there in friction between two surfaces then as the relative motion takes place it generated heat. Now, if you want to reverse it cannot happen by heating it up again. So, it will always remain irreversible. So, whether the system is isolated in itself or not.

So, with the example I give the (Refer Time: 47:36) last yesterday I think, that if liquid in a glass has been stirred it is got energy, but in the friction that energy can dissipated even though system was isolated. What will happen is between that energy where by dissipation remains in the system itself and that is a irreversible process. We cannot expect that by heating that liquid they it can go back into motion that is not (Refer Time: 48:00). Next is why specific heat at constant pressure is greater than specific heat at constant volume ok. For this question, you will have to wait till the third module, then we will pick up this answer there.