Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

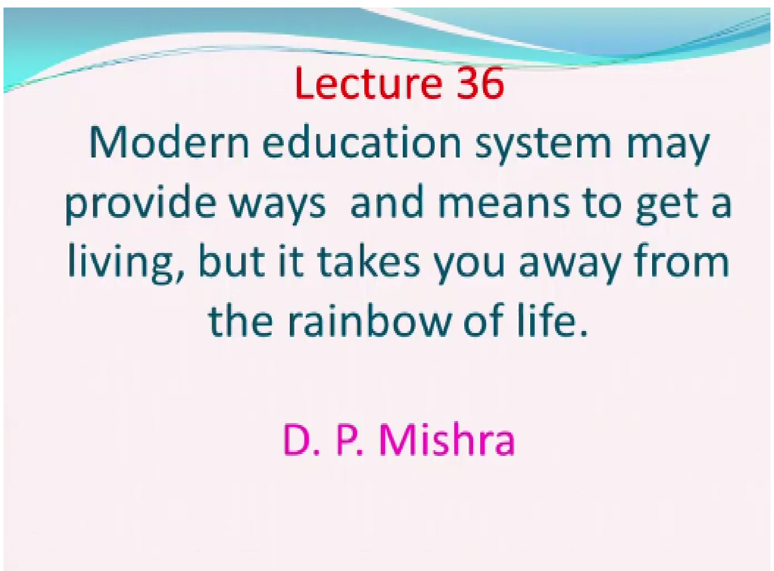
Course Title
Engineering Thermodynamics

Lecture – 36
Gas-Vapor Mixture and Air Conditioning 2

by
Prof. D. P. Mishra
Department of Aerospace Engineering

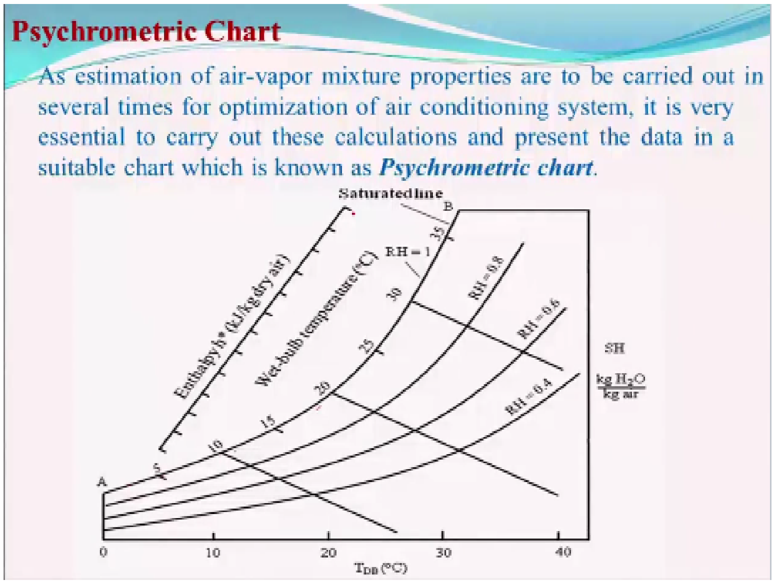
Let us start this lecture with a thought process.

(Refer Slide Time: 00:18)



That modern education system may provide ways and means to get a living but it takes you away from the rainbow of life even today it is not giving you the job, so now earlier in the last lecture if you look at we are discussing about various temperature like a dry wall temperature. wet wall temperature, adiabatic saturation temperatures and other things and we learned that how it can be related to the relative humidity and specific humidity, and we will look at this you know all these properties can be put into a chart which is known as psychometric chart.

(Refer Slide Time: 01:03)

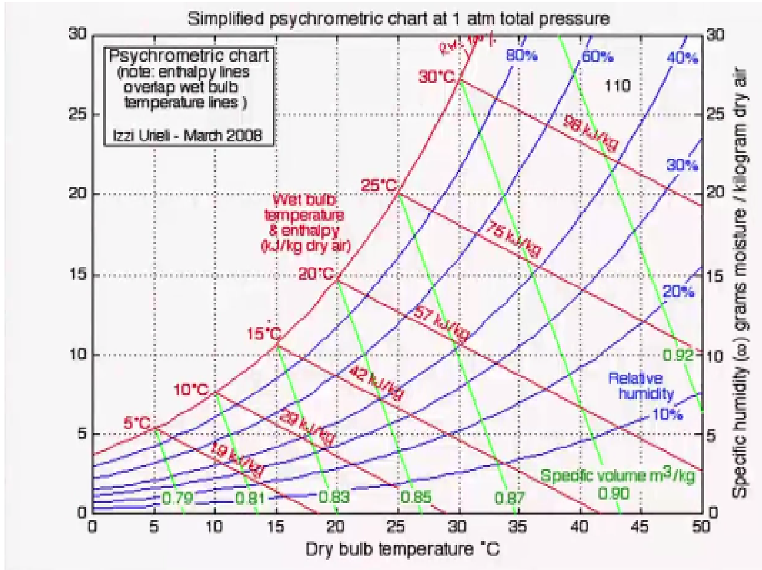


And that is very helpful for doing the calculation easily and as we have seen that it is quite cumbersome to calculate all the things of course nowadays the computers are there and then you can do all those calculation very easily but earlier days there was not such kind of provision was there, so therefore people device a psychometric chart to carry out the calculations you know they devised the psychometric chart, so that it can be utilized very easily in the subfloor right and of course they will do all the calculations and put into that into the picture.

So the typical psychometric chart is shown here if you look at that here on this protocol you can say that horizontally it is shown that is TB this is a dry wall temperature 0, 10^0C, 20^0, 30^0, 40^0 right and in the vertical line this is of course the along the horizontal line the dry wall temperature zone and the vertical line here it is on the specific humidity that is kg of water per kg of air right and this line if you look at this is basically giving me the article wet bulb temperature right which is also this line corresponding to the RH =1.

That is the relative humidity right and keep in mind that and this relative humidity is parallel to this line let us say this is a 100% relative humidity 1 and related in 0.8 it is given here and relative humidity 0.6 and 0.4 0.2 to it will be given right and this scale so the enthalpy of the moist air that is kilo Joule per kg of dry air right that gives the enthalpy and also the specific volumes and other things will be giving let me just show you this is just to illustrate this point. These are all given together in a plot and that we call it as a psychometric chart.

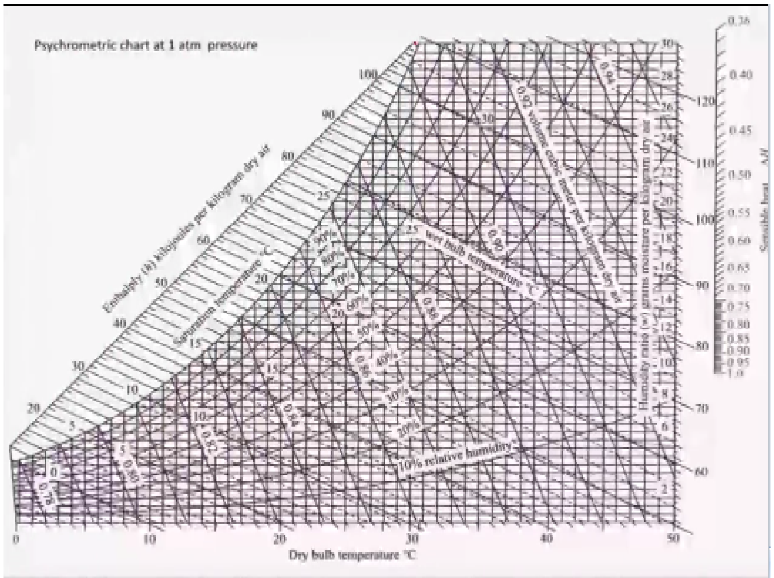
(Refer Slide Time: 03:30)



And if you look at it is the same curve but only I am just giving little illustration you know here that if you look at these lines blue lines you know relative in 10 % this is 12 % is 13 % and goes on until this end this is basically 100 % right relative humidity and these what you call lines right green lines if you look at it is basically the specific volume and this line red line is the enthalpy line like 98 kilo Joule per kg 75 kilo joule per kg kind of thing and these temperatures 5 ^{0}C, 10^{0}C, 50^{0}C all those temperature is basically the wet bulb temperatures right .

So this may looks to be very clean and clear but I will tell you the actual vertical diagram is quite complex I will show you that.

(Refer Slide Time: 04:39)



See these looks like are you getting okay I have gone through it little slowly, so that you will have feel so now so if you look at that is you know dry bulb temperature in the horizontal line this is your dry wall temperatures right this point like 0^0C, 10^0C, 20^0 like that and here this point this line is basically gives me what you call specific humidity right these 2 there will be 4, 6, 8, 10, 12 you know like all those things that is gram of moisture per kg of dry air this is in grams right okay.

Are you getting these are you know like 2 gram, 4 gram, 6 gram you know 30 grams like that as I was telling this line that is earlier it was a green line you know like this line is basically volumetric you know volume specific volume per kg of dry air the water vapor volume right but dry air and these dashed line if you look at this dash line are basically wet ball temperatures like you know if you look at this is the weight ball temperature like in this case is 25 in this case is 30 and then it goes 20 and like that like 5, 15, 10, 5 and these lines you know it gives me enthalpy of the moist makes a kilo joule per kg of dry air right and what else is there in this the one very important point is the relative humidity.

This line is if you look at this line is basically live 10 % 20 % this line right these lines are basically relative humidity points right okay so if you look at it contains a lot of data in one plot and that we call it psychometric chart at one atmosphere pressure right if you want a different thing it will be different right for example when you are going for a higher altitude the pressure will be lower then, you will have different values and little bit changes so now if you recall that we had taken a temperature you know like what you call dry bulb temperature right.

And we also looked at the wet bulb temperature as 30^0C right and we can solve this problem what we had done by calculating and considering it as adiabatic saturation saturator right all kind of things that we can do very easily here we have done a lot of calculation but here we can do very easily what I will do I know this dry bulb temperature that is for today that means I will have to go through this one right this point.

What I will had to go through I will have to go for this 30^0 wet bulb temperature is what this is your wet bulb temperature which one this dash line the solid line is corresponding to the enthalpy okay the dashed line corresponding to that means it will be crossing here irrigating that is the point. Please be careful and look at again like this is my wet bulb temperature I do a vertical line this is my vertical line right and my temperature wet bulb temperature is $30^{\,0}$ this dashed line it is coming and crossing here.

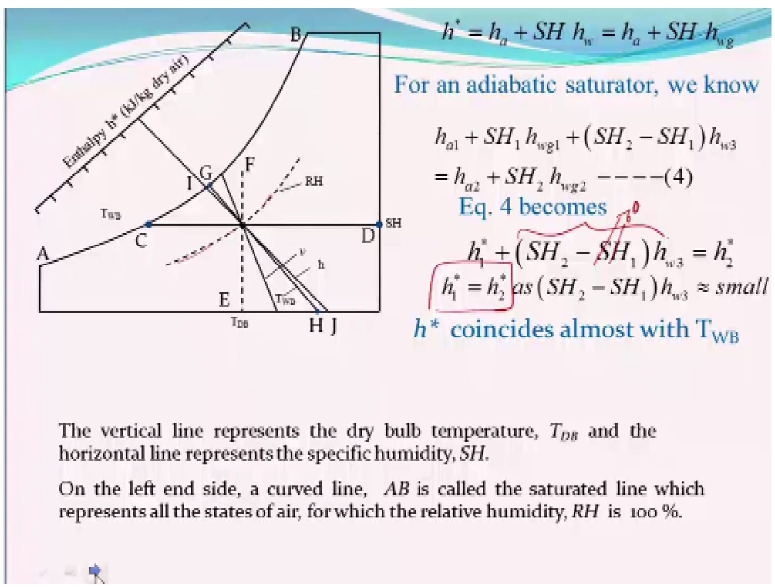
So what will be my relative humidity here what will be my relative unless this is 40 and this is what 50 this line is 50 or not this is 50 relative humidity and this line is 40, so here it will be around you can say 0.45 you can also do a linear scale and then interpolation you can do that okay but let us say that the relative humidity will be in this case relative humidity is RH_1=0.45 earlier how much you got how much it was 0.497, so that is the error by calculation we got 4.97 you can say it is 0.5 but here it is 0.45.

There is an error in that and then I want to have a specific humidity what I will get how will get what I will do I will go at this point I go directly here right this point that this is 22 right this will be something 23 right that means I got SH_1=0.023 kg of water per kg of dry air right this is in grams therefore it will be 23 grams, right are you getting so earlier how much you got how much that we got 0.00.0237 right from calculation this is from psychometric chart right psycho right chart from calculation we got SH_1 = 0.0237right there is an error of course but it is very quick.

So what is the enthalpy we got what are you going to help me and tell me here you know approximately around 100 this is your enthalpy, so from psychometric chart we are getting enthalpy of mixer is hundred kilo joule per kg but here how much you got from calculation we got HM_1 is 101.2 kilo joule per kg, so it is approximately you know so quickly because I need not to do the calculation are you getting the efficacy of using psychometric chart right quickly you want to do something you know in a subfloor are in a very complex situation you need not do all those calculations right.

Of course nowadays it is very easy you are having a program you just give then why and press a button it can come that is it okay the situation has changed but this still being used in the subfloor right, so you should learn how to use this psychometric chart for solving the problem right is that clear to you people are any doubt can I repeat again okay so as you do not need then let me not repeat.

(Refer Slide Time: 12:03)

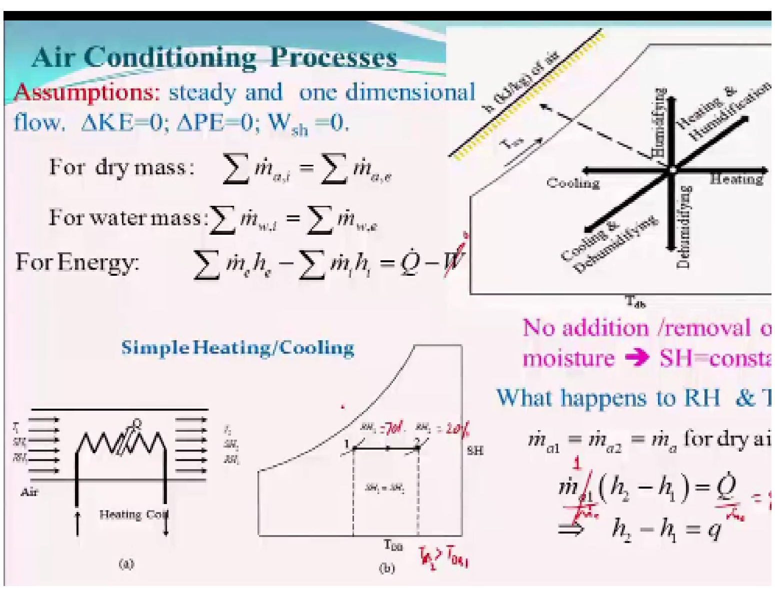


So now just to illustrate little further what I will say that you know if you look at this is the point what is this point this is your specific humidity remaining constant along this line right that is the parallel to your TV will give and this line dashed line is RH relative humidity and this line will give me enthalpy right and the GH if you look at that will give me wet bulb temperature it is you know sometimes it crosses sometimes it goes slanting right is not same as that of the relative women it but it is very the wet bulb temperature is not same as that of the enthalpy but it is very closer to that.

That you should keep in mind right and of course this vertical line if I go it will give me you know dry bulb temperature, so this is the way how you can go about so if you look at I am like which we have already seen is that H* this is what I am using here you may not get in other place but I am using h_a + SH into h_w and of course this is corresponding to the gas to right WG and for the adiabatic saturator you can get all those values I am like we have already discussed and keep in mind that this if you do that h_1 * SH2- SH1 into h_{w3} this already we have done is equally as 2* and if we would look at this is basically a small quantities you know this is a quite a small quantities right.

So therefore this is you can neglect and that h_1* is you know is equal to S_2* that you can say I mean in saturated adiabatic saturator so therefore h* coincide almost coincide with the TW you can say right and of course I have already talked about the vertical and replace the drywall temperature and the horizontal line refers the specific humidity.

(Refer Slide Time: 14:42)



And the so now what we will be discussing basically about air conditioning process and if you look at air conditioning why we need we need you know not only the maintain the temperature but also the maintain the humidity as I told in the last lecture that humidity plays a very important role depending on the you know temperature right, so and we need to also the maintain temperature and very well because you know you give you have to maintain your temperature body temperature which is maintained around 37 ^{0}C and if it is a summer then what will happen if it is 40 or 45 kind of dig tell you what we experienced then the body cannot give out the heat.

It will be uncomfortably as temperature gradient you know like okay so body has to give heat to maintain the temperature because body is like a human body or animal body other things also like you know they are like a heat engine it gives out energy right so in the winter it is other way around like it will be giving more amount of heat to the atmosphere because the temperature is lower you know that if temperature goes below 10 degree Celsius it is very difficult to you know this what you call to sustain and your comfort level will be lower right.

So therefore we need to maintain temperature also the humidity so we will be looking conditioning the air for that process let us see that what we can do. I mean to maintain this relative humidity and also the specific humidity and then you let what you can they you can think of doing the heating when you are heating you know right of course the specific humidity can think of you can humidify it right you can add some water you can de- humidify it that means you can remove some water from the air you can pull it you can cool also dehumidifier various process one can think of and that is nothing but your air-conditioned right what will be discussing.

So we want to analyze this air conditioning systems what we will do we will have to you know do the our standard assumption because it is a pro process that is the steady flow process and we consider one dimensional for simplicity actual case it will be three dimensional you know kind of thing but we are for our case we are considering one dimensional also the uniform flow you know tow need not to be uniform in a nautical a air conditioning duct and air conditioner right.

And change in kinetic energy is 0 change in potential in 0 and we are not using any soft work for this but you know then we can consider to be zero shaft work so these things will be doing all the you know cases I need not to repeat and then what we will do we will a mass balance dry mass balance that is for the a summation of air mass flow rate at the inlet is equal to summation of air mass flow rate at the exit of a any duct whatever we are considering and the water mass balance summation of water mass flow rate.

At the inlet is equal to summation of mass flow rate at the exit and will be doing the energy balance you know a summation of the enthalpy at the exit minus the summation of enthalpy at the inlet is equal to Q dot minus W and shaft work we may neglect most of the time will be neglecting but heat always will be there you know like so we cannot neglect so this is let us look at simple heating or cooling right.

Let us look at simple heating coil we are having there is a some flow rate which is entering into this duck with a temperature t1 and SH1 that is specific humidity and relative humidity and then when you heat there will be change in the temperature definitely because you are heating right if you are eating what will happen temperature will increase right so what will happen to the specific humidity what will happen to the relative humidity right.

So the specific humidity will not be changing why because you are not adding any water vapor or water right whatever into the system so therefore specific humidity will be remaining constant but then what happens to relative humidity what will happen and what will happen to the dry bulb temperature definitely you know what will happen because you are adding heat when you are adding heat then there will be increase in temperature right.

And if you are you know not adding any moisture but you are increasing the temperature right so what will happen to the relative humidity relative humidity is the basically ratio of the water vapor divided the maximum water vapor it can take with the temperature what happens to the you know saturated pressure if temperature is increasing the saturated pressure will be what increasing right yes or no it would increases then what happened to relative humidity relative humidity will be lower right.

So if you look at the process you are here and you are heating it so therefore what will happen that it will go to this process see our state to and TB is higher this TV db right is greater than the TDB1 yes or no right because you are heating and the relative humidity gets reduced right and you can do this analysis the mass is conserved right for this process mass of dry air right and water also is conserved.

Because you are not adding anything and if you do energy balance that is in this equation you know right if you do there is no sapped work here so therefore m.a1 s2 – m.h1 because you are not adding any water so therefore only air will be there is equal to Q dot and if you divide by this

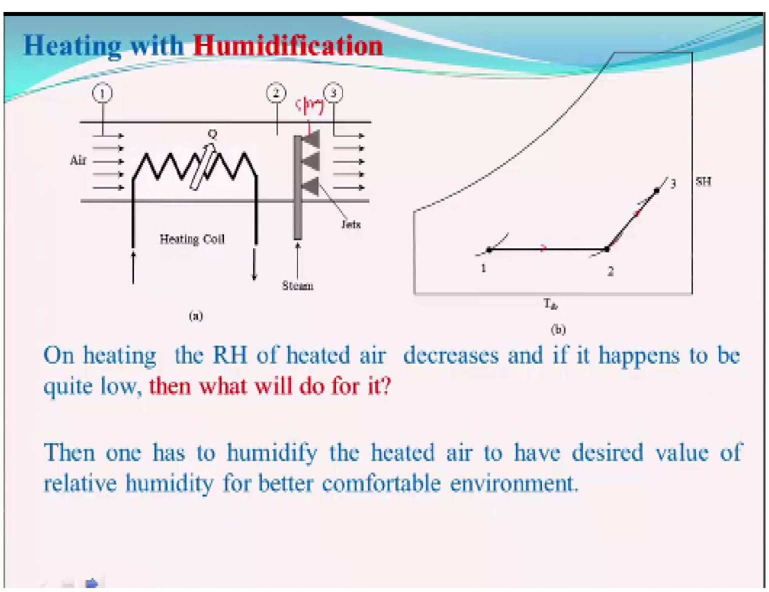
$m._a$ and $m_{.a}$ here m. a here this will can one and that is nothing but your Q so s2 - H 1 is equal to Q right as a result the TV TD be at the station 2 will increase and relative humidity is increasing.

You know let us say that Rh2 = 20% and let us say this is your seventy percent kind of that means 70 to twenty percent it has gone if it is the relative humidity is very low what will happen in the winter season let us say you are using a heater the relative unity is being is the lower so what problem will face your scheme will be dry right and some people may get you know like what you call jittery kind of things right.

So if it is dry you may be getting itching and other problems you know like so then you cannot so now what is the way out of course you can get the similar problem similar some other like in opposite of that whenever you are cooling suppose cooling means I will be giving the cooling here so that if you are at station 2 you will be going towards the station 1 then there will be increase in the relative humidity see if it is a late immune case and temperature is very low so what will happen it will be you will be also uncomfortable right.

So you go both the side you will be having problem so we will have to look at it what do I do therefore in the winter season when he use the heater in your room you will find you know dry skin you are getting more right that means you will have to you humidify that means you add some water moisture so that you will not face that problem.

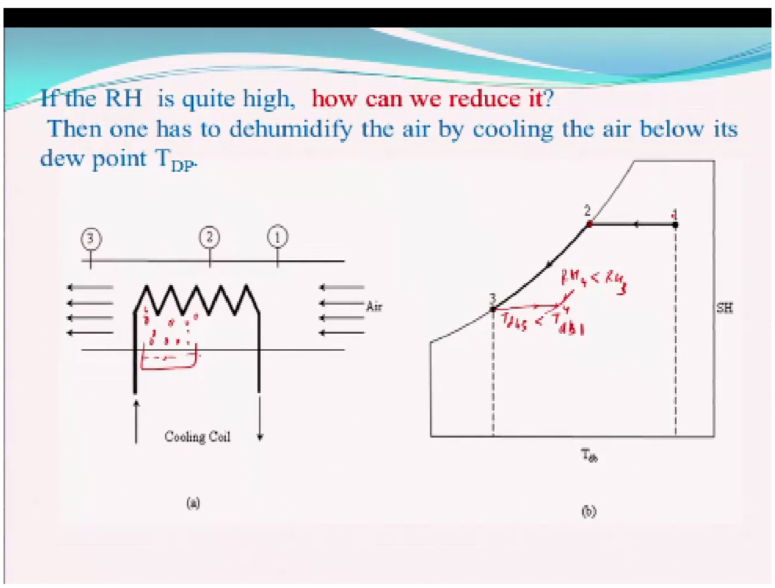
(Refer Slide Time: 23:28)



So as I told that one has to humidify the heated air to have desired value of relative humidity for better compatible environment and let us say heating with humidification we can do that like you can think of adding you know like a this is the heating coil and then you can add some steam and some spray kind of thing you can use right and so that it can moisture like what will happen one to two you are heating that means specific humidity is remaining constant.

And from two to three what will happen like you will be adding some moisture so the moisture content is increasing right and then the specific humidity increase also the what will happen to relative humidity relative humidity also will increase because this is a lower and this is the higher so relative humidity will increase so that you will be more comfortable and dryness and other things probably whatever it will be airing. So this is known as the, these things like heating with the humidification.

(Refer Slide Time: 24:33)



So if the relative humidity is quite high right as I told like if you are cooling it right you are in twenty percent you will go to seventy percent or you may go to ninety percent right so what will happen how can we reduce that is a very simple answer that I already told you that we can do you me to buy air by cooling the air below its dew point temperature right so you can think of using the you know cooling coil here and this will be low temperature and it will be a high temperature then what will happen you will go from you are here right.

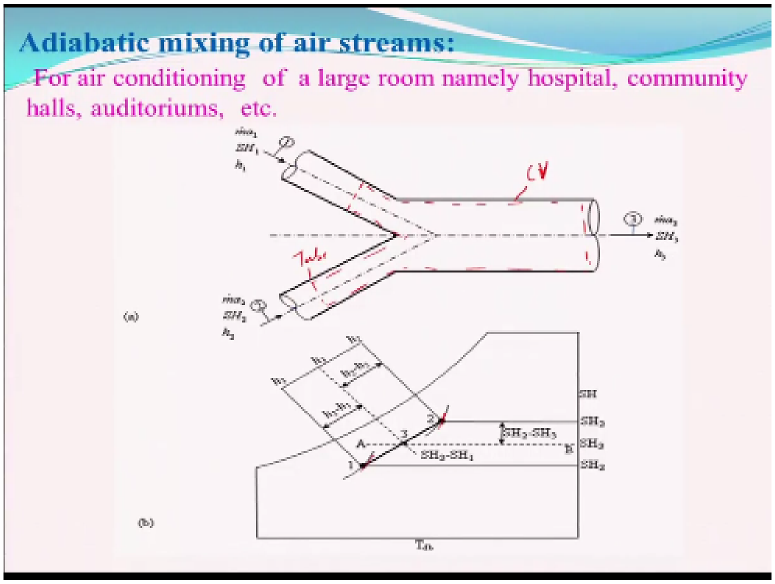
You are here and then when you cool it so you will come to this point that is your wet boiling temperature right dew points so that after that what happened it will be hundred percent relative humidity will be hundred percent at this point so then it will be started Deeping in like if you look at there will be some moisture we can collect over here you know these are all moistures which are condensed you know condensing moistures which are condensed and coming as a droplets and then you can collect it hey you can collect that one.

And then as a result the a, you know the moist air which is coming over here it cooled and then you will get over here then now here also the relative humidity temperature is lowered downright db has come down herein this point db is what to come dv three is very less than the dv 1 db one right but however the relative humidity is one hundred percent.

So you have not solved the problem so if I want to get you know something lower relative humidity which is comfortable what I will have to do what I will have to do I will have to again heat it right again hit it if I heat it then what will happen it will go this way right because specific humidity is remaining constant then I can get at his is your relative humidity right which is if I take this point for that for will be less than our h1 RS3 okay.

And of course this RH4 > RH1 that is the one way of solving the problem but there is another way of solving the problem that you mix some other a right which is having different relative humidity and relatively specific humidity will mix then you know you can get this thing so therefore we can think of using that which is this mixing of the different moist air and different temperature and different you know kind of things is being used routinely in air conditioned applications right.

(Refer Slide Time: 27:32)



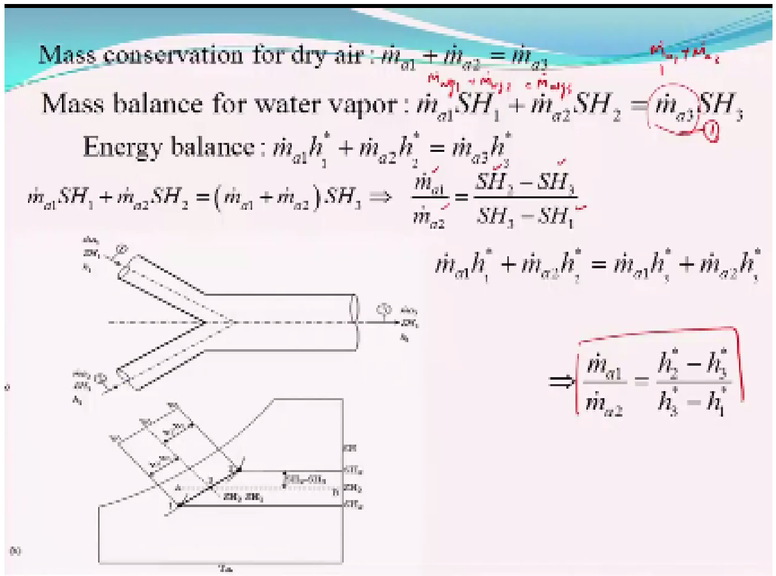
So we will be looking at the annual rating mixing of airstreams right okay so in this case you know particularly this is being used for large rooms like hospital like your this auditorium like lecture halls community halls you know kind of things where you need to mix the air and then allow so that people can have a comfortable zone, so therefore let us look at a typical case will be looking like that like you know there is a one stream is coming with SH up one and some enthalpy right.

O course at certain temperature and then similarly there is another stream which is entering into this tube right this is your tube and with the specific different specific community it is mixed together and then it is going and then you can give we can have a control like you can give different values of flow rate different values of specific humidity and whatever you can have then you can control whatever it is having exit at the station right.

So what will happen like I need to analyze it what I will do I will take a control volume you know something like that I can take this is my control volume right and you can I do this mass balance energy balance and other things right okay and of course you will have to use also this psychometric chart which I have shown here like this is at station 1 and this in station two if you join this thing you know and you will get in between right.

That is the station 3 you will be getting and you can use this very easily and get the you know calculations and other things so.

(Refer Slide Time: 29:37)



So if you look at we will be doing the mass conservation of for the dry air that is m. a 1 + m. a 2 = m. a3 this is general 1 and which we have done several times so similarly for the water balance what we will do is basically MW1 + MW of course this will be G 1 water vapor right z 2 = mwg3 and that we can express in terms of specific humidity mwa $1SH_1$ + MW m. $_2$ x ss $_2$ =m.at 3SS 3. Right so what a vapor we can express in terms of the mass of air and their respective specific humidity and if you can do this energy balance we can get m.aah 1+m.a_2 x s_2 + m .a 3 x s3.

Right so we can get this balance and from your this equation if I say this is equation 1 right from this equation and I can use what you call mass balance here m m.a3 =m.a $_1$ + m.a_2 here I can put it here that m. a_1 + m.a_2 that is exactly what I have written here and then you just take a what you call mass of a separate it and then you will get a relationship between mass of air at station 1 / the mass of a mass flow rate of air at station 2 =s s $_2$ - s s_3 / s s $_3$ – hs_4.

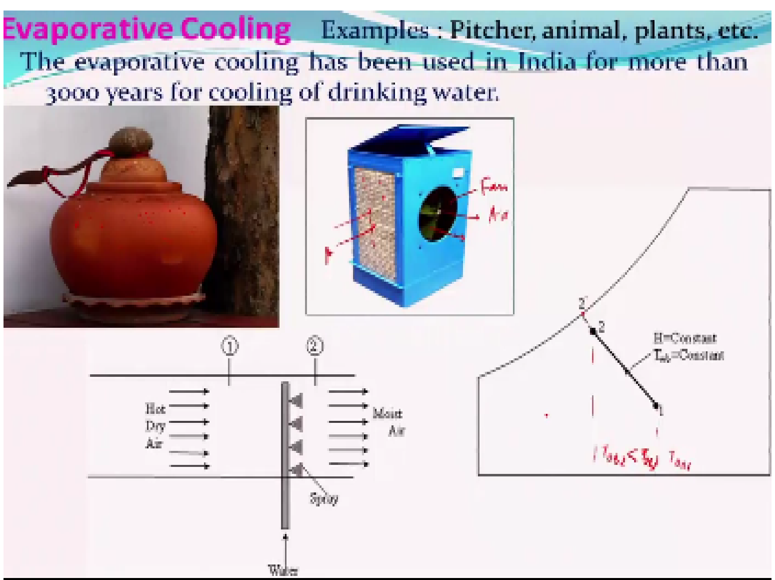
So if you look at if I know this one right let us say I know the mass flow rate I can very easily find out you know this thing what you call like from here that is the SS_2 if you look at SS_2 – and if I can find out ss_3. Right-s is 1 this portion right provided I know this values right or if I know that what is my desire level ss3 I know SH_1 this is known this is known right and if I know this is then I can find out what will be mass flow rate away from very happily you can find out what it would be right one of them.

Of course you should know that rest of the things you can find out you can tinker and find it out or what it would be. So this is a very simpler way of doing and similarly we can think of doing this from this energy balance that is = $m.a_1$ / m. a_2 =s_2 - s_3 / s 3- h_1. Right of course you know * is not being used but i have used because i have introduced and it is you can use enthalpy.

So that also you can get from here that you know h_3 - $h_1$is here because if I know this point what I want and the similarly s_2 s_3 anyone of them unknown you can find it out from here very easily right.

‘

(Refer Slide Time: 33:16)



So what we will do will basically looking at this you know like another example that is evaporative cooling right which we use in our day today life particularly you know evaporative cooling is as old as Indian civilization.

You know and the examples if you look at pictures even our human beings animals plants all use the evaporative cooling to keep the body temperature and other things right that is why we sweat. You know like and then that will be evaporated and our body will be you know maintaining it is temperature. So as I told that evaporative cooling is known to us for more than 3,000 years for which are used for cooling of drinking water.

Right the examples you know very well the picture right and picture are not being used nowadays because there is a not many people who can really make the feature. I am sorry to say this because that is the state of the art because if you buy a picture from the market it was not having porous people have forgotten how to make the porous how it does work it will be having very tiny porous will be there.

Right and through the pores right through the these pores that water will be coming out of course the depending if humidity is not much you know like a little dry is there and then that will be evaporated but today you will get the peaches the pores are not there they are forward and how to make the pores therefore you are not getting very cool water. Right okay it is very unfortunate we lost that technology which he was there for as / 3000 or may be 5,000 years back but we lost in the process of modernity.

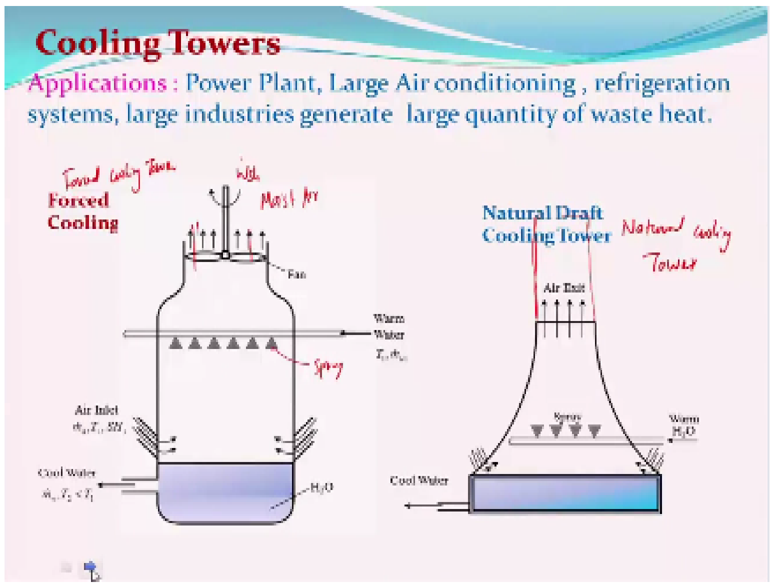
Right and this thing also in our coolers which you call you know air cooler right we call it and this is known as desert cooler also ore swamp cooler because what happened if it is dry you know then dry that means not much not much water vapor is there in your air like your northern belt of the land like in you know can New Delhi, Rajasthan other places before the monsoon.

This is a very beautiful system which of course I use in my home and this coolant and this is being devised by us right and what it does is basically sprays the water and the hot dry air enters x it you know this you can model that way you know these are the you know water will be there here it will be kind of things. And then air will be entering to that and it is suck out you know this is your fan exists and what we use and then you will get the cool air because of evaporation.

Right and if you look at what is happening here as the process is basically enthalpy will be remaining constant and also the wet bulb temperature remaining constant but if you go beyond it you know then water will be anything and it will be moist is not good. So therefore people try to you know these things. So therefore designing of that also is very important what surface area will give what are the things how much you can close you know like or such that it can really keep the temperature lower.

So if you look at you are earlier here tdb1 and this has been reduced you know tdb2 to so if it is less than the tdb1. So you are getting the lower in temperature so that is the thing what one can think of using you know we use it and analysis will be similar in nature.

(Refer Slide Time: 37:20)



So the another examples I would like to give that is known as the cooling tower which we use for the power plants and enlarge their cunning system and Refugee essence system laws industries you know. Right because we use a lot of you know particular in industries last quantity of waste water wastewater means heated water basically and then that can be cooled down very easily.

Right and if you look at you know in our campus itself there was a cooling pond which you might have seen it is in the develop 88 condition at this moment that is located in front of what library center language right and that is the pond which was being used for air conditioning the our library earlier but now they are replaced and that is a beautiful system.

And it is also beautify our camp you know places earlier there was a fountain and use you that so typical cooling tower looks like this like if you look at there is a water warm water enters over here right which produce the spray that means water will be sprinkle put x droplets surface area will increase. So that evaporation will be you know enhance and then there is a fan which is being used.

Right and this fan will suck the air and we will take the mall air also here and this water which will be spread down and will be coming over and collected here and at evaporation is taking place some of the water will be going through this you know this is the sum of the moist air right which will be going through that because it is evaporated going through.

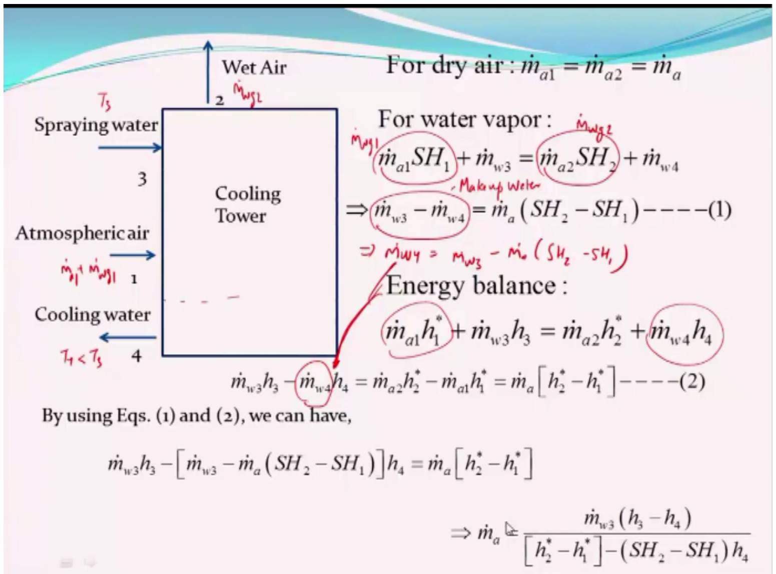
As a result what will happen the water whichever is you know you know this thing there will be lower that means less amount of water will be collected here then whatever enter is going to and that water you know difference we call it as a makeup water. You know like because the difference will be there due to the evaporation some of the water vapor will be converted x its vapor and carried away by air.

This happen this is war even have to give some power you know like it is some soft power allure to give you will have to use some energy for that but there is another way this is where the spray will be there it is having same collected but this is a what you call chamber. Which is given such that you know it will be take the air naturally it is a very long I mean I have shown in very less but actually it is a very long towel.

This is known as the kind of things and this is known as natural right cooling tower it is like a community mean you know like you know you might have seen per hour here in Kanpur area like you were having lot of brick industry the chimney will be there all kind of thing and this curvature you know which is very important for the designing and how it will be taking care of that part.

And here it is known as forced cooling tau right force convection you can say right tower because it is you are using the you know fan which will be taking away here there is no energy is required to be going automatically because the water vapor is lighter is not it because it is molecular weight is much lower than the air. So therefore once is converted x vapor it is very lighter and it will be carrying our thing so how we going to analyze that.

(Refer Slide Time: 41:18)



So as I told this is forced cooling tower and then we can think of using basically two thing one is atmospheric air is entering right. Okay and the word a are going out and spraying water is coming which is one other very higher temperature right if you can think of this is p3 right and this cooling water is going out at the end you know there will be correct collected here and is going out.

This we are trying to model basically and this T for so T 4 is less than T 3 always otherwise you know what is the purpose okay so therefore if you look at what we will do we will do the mass balance for the dry air that is mass flow rate of air at station 1 =mass flow rate of air station 2=mass flow rate of air.

Right and we will do the water vapor right and this is if you look at this portion is nothing but your MW g1 and the if you look at this is coming with the atmosphere which is entering x tower+ the amount of spray water which is coming mw3 simply what nothing else ok this is a warm water =mwa tox SS 2.

So this is the amount of water vapor going out at this point right this is your mwz2 right and this is your mwg1 mwa1 right + this will be totally right total air is coming. So mw3which is mw for which is the cooling water right this is a cooling ordinance. So what do you do you basically you can say that this is mw3 - mw4 is nothing but MW sorry as flow rate of air because by mass balance.

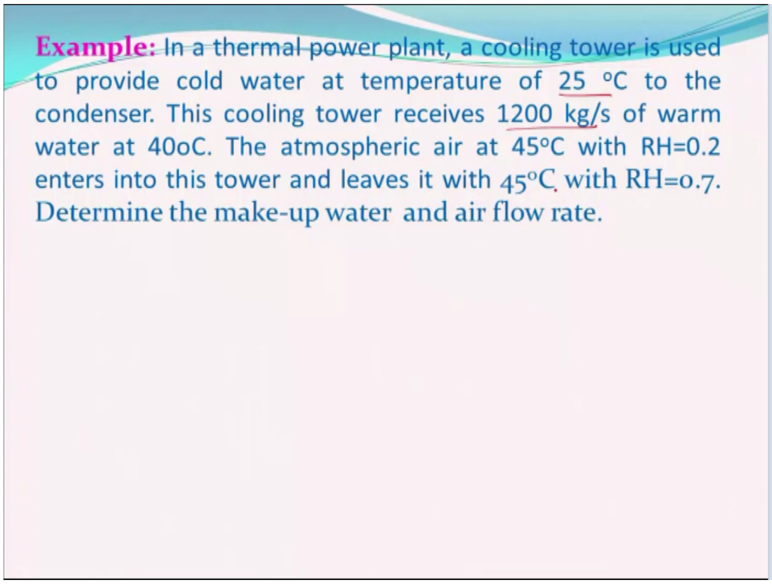
Right we know that x s s2 - s1 and this is known as the makeup water right that means this is even the difference the MW3 - m w4 what is the difference that is the amount of air which goes out of this cooling tower you know through the station to write so and we can do energy balance like that is the enthalpy at the station one here. Right and x the enthalpy which is entering x the cooling tower right to the spray bar what we are using is = the enthalpy is going out at the you know exit from this and M.

And then enthalpy of the cold water this is your enthalpy of the cold water which is going cooling tower. Right going from the cooling tower so the if you do that then you will get basically I can take this out mw_3 s $_3$ that is your this term- m w_4 h $_4$ =mw is = ma $_2$ s_2 - m . a_1 h $_1$ and of course $m.a_2 = m.a_1 = m.a$ so therefore there is a change enthalpy right you can take out.

So in this case what we are doing in place of your mw4 I can use this expression that is MW 4 =MW 3- M was h2 - h1 and I can use this expression over here right I canoes this expression over here and then Incan get this expression that is given like me de MW 3 s 3 - this is the bracket degree you know like for the mass flow rate of water at the station for into enthalpy at station four is equal to change in enthalpy you know between the station 1 and station 2 so I can find out the amount of mass flow rate of air.

Which is entering you know into the cooling tower =M We into S 3 - H /by s 2 *- h1 - in the bracket s s2 -s1 into h 4 so this way we can you know what you call calculate the amount of this thing we can use this expression right so I can take an example right just to you know solve a problem that in the thermal power plant a cooling tower is used to provide old water at temperature 25 ^{0}C to the condenser right and these cooling tower receives 12^{0}kg per second a warm water at 4^{0}C and the atmosphere at 45^0 with rah of relativity opoint2 enters into the tower and leave sit with a 45 ^{0}C.

(Refer Slide Time: 47:09)

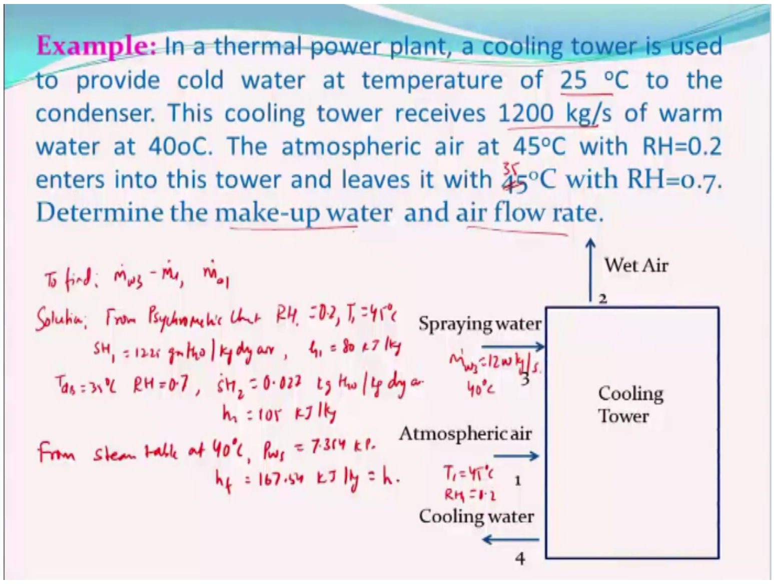


Right with relative humidity of 0 7 and we need to find out makeup water right and air flow rate so if you look at what are the things are given here see if you look at like your t 1 is given t1 is 45 ^{0} C right and our h1 is 0.2 and the this thing is leaving you know like what you call the cooling tower receive sunder 2^{0}kg of water right these are the three this is your basically mw3 is 12degreedegreekg per second and this is at 4^{0}C right and we need to find out to find basically mw3 right this is the station 3a- m w4 and allure to find out mass of air how much air is entering so what we'll have to do we will have to basically we can use the psychometric chart right.

From psychometric chart we can get that is pointing to 45 ^{0}C right and RH^0.2 so we can get very easily that is our h1 is degree 0.2 and t1 is 45^{0}C I can guess sh1 is 12.25 gram per water per kg dry air right and we can also get the from the same psychometric chat we can get the tdb that is dry bulb temperature 35 this would be 35 ^{0}C okay 35^{0}C this is not 45 there is 35^{0}C.

And our H =0.7 so I will get sh2 is 0.027 kg of water into kg of dry air okay h2 I can get 1^{0}5 kilo joule per kg okay and these are the data we need andh1 we can also find out from psychometric chart that is h 1 is equal to 8^{0}kilo joule per kg okay and from steam table at 4^0 C I can get pHs = 7.384 kilo Pascal he 16 74.5 4 kilo joule per kg and which is nothing but your H what you call three right this is the station three right and at 4^{0}at 25^0 right cold water pw s = 3.1 69 169 kilo Pascal if 1^{0}4.8 7kilo joule per kg and which is nothing but your h4 is h4 right.

(Refer Slide Time: 51:02)



And so what we will have to do we'll have to basically do this energy balance and then misbalance and then we will calculate because we know all those dates' right and by mass balance for water we can get MW 3 + m was so one that is entering one and three entering is equal to m w4 + ma to SS two so if you look at what is mw3 met is nothing but you are given twelve hundred + m . and so one is given $^{0}.^{0}$ 1 225 I am using you know kg per of water per kg of dry air =m w4 + M Watts into d.0.02 27 that is to right so you can use this equation 1 and x energy balance I can get basically MW 3s 3 + MW a h1 =M w a s 2+ mw3 h4.

So from this I can get basically mw3 right h3 - m w4 h 4 is equal to M was s 2 - h1 and we know this thing h1 is known s2 is known and we do not know ma but mw3 is known and four is not known so we can write-down here like that 12degree^{0}into a h3 is known that is in 216 7.54 - m w4into this is known h4 is known so 1d 4.87 =what you call m. a into185 - eighty this quality we have known from the psychometric chart we know this thing so you will get equations hear.

So if you look at this if you .hat solve this thing equation one and equation two and you know I have eliminate this mass flow rate of air In can get MW four =basically115296 kg per second right okay so if relook at what is the makeup water makeup water is MW 3 - m w4 what is mwt12degree^{0}- 1 15 2.96 which is giving me47.^{0}4 kg per second.

Equation by using equation one because I know this MW four, so I can find out MW a =3 189.15 kg per second can give you know it is very easy actually a look at what you can do you can get from here right that is from equation 1 I can get me a.d27 - degree. e1 to 25 right is equal to1^{0}-

what you call that is the is 115 2.96 so therefore we can get from here right very easily and then that is 31 89 per kg per second very easily right so if you look at by this way you can solve how much you know air is entering into this cooling tower.

And what is the makeup water one has to provide you know like kind of things so by this way you can do in this case what we have used we have used both the you know psychometric chart and we have used the steam table for the data says it' table and you can also do a little hand calculation to be you know it will be little slower like that I can do so with this will you know we have completed the what you call the psychometric of their conditioning part and next class will be discussing about a new topic which is known as thermodynamic relationship thank you.

Acknowledgement
Ministry of Human Resource & Development

Prof. Satyaki Roy
Co-ordinator, NPTEL IIT Kanpur

NPTEL Team
Sanjay Pal
Ashish Singh
Badal Pradhan
Tapobrata Das
Ram Chandra
Dilip Tripathi
Manoj Shrivastava
Padam Shukla
Sanjay Mishra
Shubham Rawat
Shikha Gupta
K. K. Mishra
Aradhana Singh
Sweta
Ashutosh Gairola
Dilip Katiyar
Sharwan
Hari Ram
Bhadra Rao
Puneet Kumar Bajpai
Lalty Dutta
Ajay Kanaujia
Shivendra Kumar Tiwari

an IIT Kanpur Production