Renewable Energy Engineering: Solar, Wind and Biomass Energy Systems

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Lecture – 11
Practice Problems part- III

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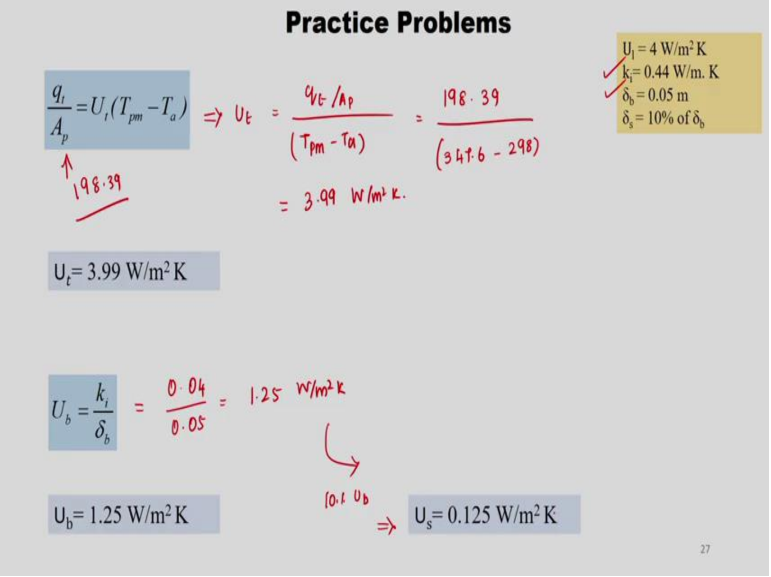

After calculating q t upon A p which came out us 198.39 we are going to calculate U t which is nothing but q t upon T pm – T a. q t upon A p is 198.39 T pm, we calculated as 347.6 atmospheric temperature is 28 or 298 Kelvin. So, for this if you calculate U t is coming around 3.99 watt per meter square Kelvin and then U b for U b you would require the thermal conductivity of the insulation material.

And bottom insulation thickness that is given here k i and bottom insulation thickness k i is 0.04 bottom insulation thickness is 5 centimetre or 0.05 meter which is coming around 1.25 watt per meter square. So, the assumption is 10 % of U b can be taken as U s so, 0.125 watt per meter square.

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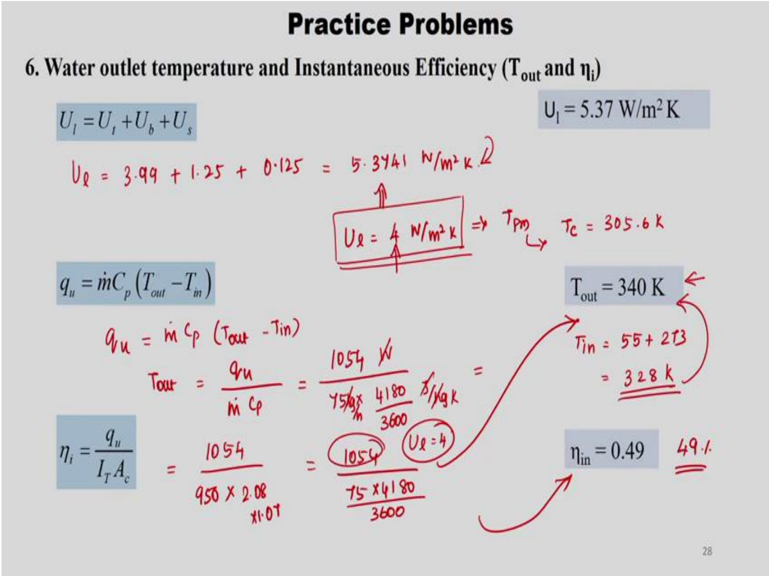

After calculating everything heat loss coefficient U l is U t 3.99 + 1.25 that is U b U s is 0.125 if you calculate it is coming around 5.3741 watt per meter square Kelvin. So, what we assumed? We assumed U l to be 4 watt per meter square and calculated T pm that is plate mean temperature and after that to calculate because the plate and cover system is filled with the air to calculate all the losses then we assumed collector temperature as 305.6 Kelvin and then proceeded the calculation we are getting now; U l is 4 watt per meter square.

So, that seems to be not coinciding, because the difference between calculated value and guest value is so much but still, we will try to see how much we are getting as an outlet temperature and instantaneous efficiency. After that we will go back and recalculate, recalculate in the sense we will assume some other initial guess for U l and T c and then proceed the calculation and see what is the final efficiency we are getting.

So, if we calculate then if we know U l, q u is nothing but m C p T out minus T in. So, this T out is nothing but q u upon m dot C p. So, what is q u? 1054 watt mass flow rate is 75 kg per hour and C p is 4180 kilojoules per kg degrees centigrade. So, here we were given CP joules per kg Kelvin and then this is CP masses 75 kg per hour. So, this is not what so, we would require this is kg per hour.

So, we need to divide it by 3600 to get into watt, watt gets cancelled and then Kelvin, it will T out will come in Kelvin. So, basically 1054 upon 75 into 4180 upon 360, so, which is coming around 340 Kelvin. So, if you see what is the wrong here the prediction of whatever we are getting the T outlet temperature as 340 is wrong by it is because the 1054 q u what we calculated is based on U l 4.

But whatever we got through the calculation is 5.3 but still we are learning the method and we will recorrect or re guess this U l value and try to predict correct outlet temperature. Once outlet temperature is known, then for T in how much we have given 55 degree, which is nothing but fluid inlet temperature here if you see 55 degree, so 55 degree plus 273 which is nothing but 328 Kelvin. So, for 328 Kelvin how much outlet temperature we got is 340 Kelvin and for instantaneous efficiency again q u 1054 upon I T.

I T we calculated as 950 and A c, A c is; the details are given here and the problem collector area length of the collector and width of the collector has given it is not a plate area it is a collector area it is a gross area so, 2.08 into 1.07. So, if you calculate eta in, eta in is coming around 0.49% or 49%. So, this is the way you calculate the instantaneous efficiency and outlet temperature of the fluid for the given data whatever we discussed in the problem.

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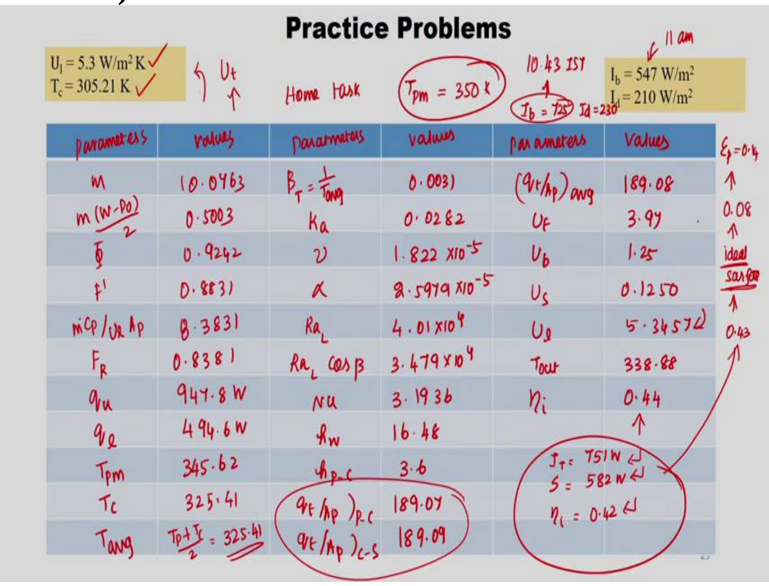

So, if you want to check correct values, so, here I have given. So, here U l is taken us 5.3 watt per meter square Kelvin and T c is taken as 305.21 Kelvin for this, what are all the parameters we are getting and what the values I am giving you can take it as a home task. And for the rest of the data, whatever data given in the problem is saved, but we assumed U l as 4 and proceeded the calculation and T c we assumed as 305.6 but here we are re guessing the U l value as 5.3 watt per meter square Kelvin and T c is 305.21 Kelvin.

We will check whether U l is coming same or not. So, I am just giving you the calculated parameters, you can do it as a home task and let us know parameters and then values so, that m is 10.0763 m w - d not upon 2 which is 0.003, phi is 0.9242. F dash is 0.8831, m dot c p upon U l A p is 8.3831 F R is 0.8381. q u is 947.8 watts, q l is 494.6 watts, T pm is 345.62, T c is this is cover temperature 325.41 then T average which is nothing but T p + T c upon 2.

Which is nothing but 325.41 then we have beta T which is nothing but 1 upon T average which is nothing but 0.0031 then thermal conductivity of air at average temperature is 0.0282. Nu is 1.82 into 10 to the power of -5, alpha is 2.5979 into 10 to the power of -5, Rayleigh number is 4.01 10 to the power of 4, then we suppose to calculate Ra L cos beta which is nothing but 3.479 10 to the power of 4, Nusselt number calculated as 3.1936.

h w is 16.48, h p-c is 3.6 q t upon A p for plate to collector system is 189.07, q t upon A p to cover to surroundings is 189.09 q t upon A p average value is nothing but 189.08 and U t is coming around 3.97 U b is coming around 1.25 U s is 0.1250 U l is 5.3457, T outlet temperature is 338.88 and instantaneous efficiency is 0.44. So, if you check your check for T c is coming correctly and the guessed value is 5.3 watt per meter square Kelvin the calculated values 5.34.

So, pretty much this is converging this particular value of U l and T c for the given data. So, now, as I said earlier to guess correctly you might do it twice or thrice or if you have experience and pretty much for this simple liquid flat plate collector mostly the plate mean temperature would be around 350 Kelvin. Last time we got 346 but how much 345. But the thing is why are we supposed to balance this exactly here is that is where we learn certain thermodynamics laws.

So, you cannot for example, the heat loss given from plate to cover system should be high than cover to surroundings. So, you should be having higher temperature in the cover and lower temperature in the surroundings. So, if the reverse happens for example, if your absorber plate temperature is less than that of the fluid inlet temperature then instead of getting heat it will give away its heat fluid will lose its heat.

So, these are all the places you are supposed to apply the thermodynamics laws and check whether you are doing it correctly. So, pretty much and also this U l why we are calculating

U l is to find out U t that is top loss coefficient, but for there also you have many correlations which predicts the top loss coefficient if that is the case U b, U s is straightforward you supposed to calculate the area and then thickness and thermal conductivity values are available.

So, with that also one can calculate for U t also, if there are correlations available, then you can directly use that as well. So, here we have discussed all the possibilities and how to do the analysis in depth. And one more thing I would like to emphasize here is for the Indian standard time of 10.43 the value we have taken that I b as 725 and I d as 230 that is like for very hottest environment.

So, normally that may not happen around 12 noon you might get this high radiation of watt per meter square. This also be discussed. So, here we have taken this value just to show you the performance analysis even for that high I b and I d how much we got instantaneous efficiency is 0.44 only. So, here as I said earlier, you can plug and play instead of taking 725 and 230, if we take 547 watt per meter square and 210 watt per meter square.

This is pretty much for 11am of Indian standard, any decent hotter cities, so far that the eta is coming around. So, this is separate problem for that the I T is 751 watt and s is 582 watts, and the instantaneous efficiency is 0.42, everything is lower than that. And one more thing also here to mention, we have taken epsilon p as 0.14 that is nothing but the emissivity of the plate, which is 0.14.

So, this value also it is like higher for any good absorptive surfaces because the plate should absorb the solar radiation and for this instead of 0.14 if you assume 0.08 that is supposed to be called as ideal surface ideally it should be 0 the emissivity, we have taken 0.08 then what you would get efficiency as 0.43. So, for 0.43 this value is I kept for I b of 547 watt per meter square I d of 210 watt per meter square I T of 751, s of 582 if we just change the plate emissivity value as 0.08 instead of 0.14, you would arrive with 43 % efficiency.

So, like this, you can change the given data and see how your efficiency is affected by many other parameters by here it has shown is like we learnt in the first lecture itself, solar radiation is nothing but a shortwave radiation and from there radio waves as well as the visible light would reach the Earth's surface and for UV and IR it is reaching the Earth's surface in an attenuated form. And if you see gamma x rays, they would not reach the atmosphere.

So, the Earth is having a temperature less than that of the sun and it reradiates basically. So, when it reradiates as a long wave radiation. So, the plate material if it reradiates more or if it emits more, then that is not of much useful. So, here there are many research groups working on this particular surface modification itself how to get higher absorptivity and low emissivity.

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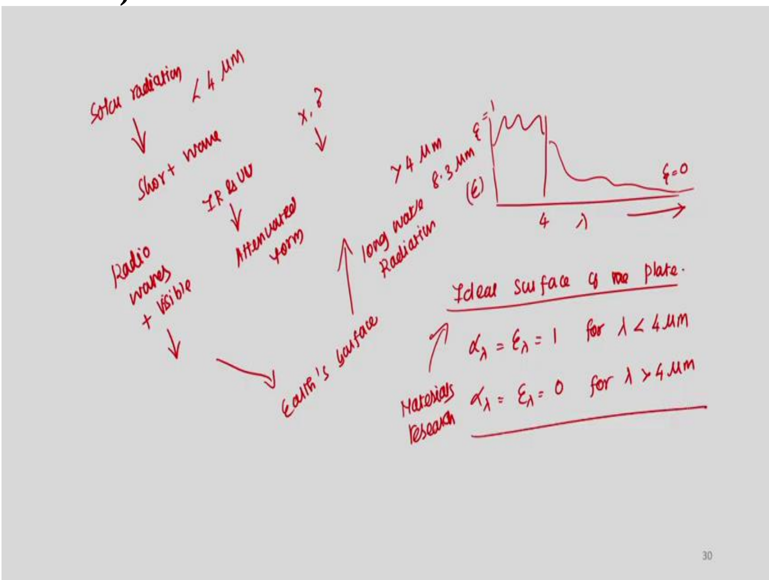

And also, if you remember solar radiation reaches us shortwave radio waves plus visible light reaches the Earth surface and IR and UV in attenuated form and if you see gamma x angle, they will be filtered by the atmosphere itself when it reaches the surface it radiates back as a long wave radiation because, Earth does not have that much energy to radiate us shortwave. So, here if you see there is a research article on which it said that the solar radiation the wavelength range is less than 4 micrometre.

This we have discussed in lecture 1 as well you can refer it, but when it reradiates, it reradiates greater than 4 micrometre, especially maximum at around 8.3 micrometre. So, there is an article in that. So, for this purpose, normally the ideal surface what I was talking about is ideal surface of the plate. So, for this the alpha lambda which is equivalent to epsilon lambda we just kept at around 1 for lambda, lambda less than 4 micrometre that means solar radiation, but if alpha lambda, epsilon lambda is 0 for all lambda greater than 4 micrometre.

So, this is ideal, but how to get in reality because we already know there is no perfect blackbody. So, how to get them in reality there are certain research groups working on that materials research to get this particular ideal surface, but we are not getting into that. So, what I wanted to make is so, this particular radiation for that emissivity should be 1 and for all longwave radiation, the emissivity is going to be around 0. So, if you see this is lambda, so, this is around 4 and this is higher value of 4.

So, this is nothing but emissivity data. So, here that is what I told you. Instead of emissivity of the flat plate as 0.14 you can take it as 0.08 and be calculated as 0.43 for this given data, the same way you can work around for example, this data we have taken as 1 glass cover system. So, if we put more or 2 or 2 above than that, whether the losses because the cover system its function is to protect the plate from environment and also you should allow the solar radiation to absorb and the absorber plate and it should emit less.

It should prevent the convection and radiation losses. So, in that way so how many covers glass covers would be required. So, that analysis you can make and change the fluid temperature fluid inlet temperature and check whether efficiency is increasing or decreasing. And as I said earlier, instead of instantaneous efficiency you can also calculate in terms of daily or hourly efficiency because radiation is slow phase.

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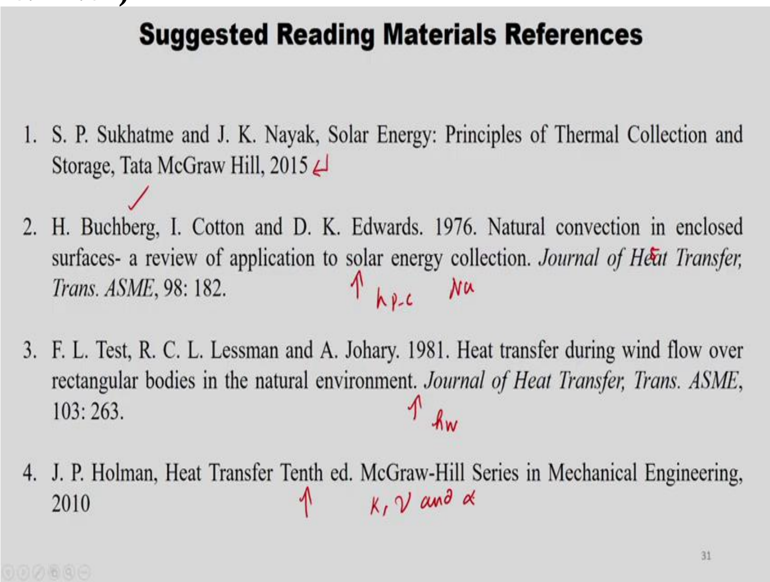

So, that is all and here are the references the basic design of problem is taken from Sukhatme and Nayak for all collector details and Buchberg, Cotton and Edwards Buchberg cotton et al is used to calculate h p-c value, the Nusselt number correlations whatever be used in this lecture and test et al. This is used to for to calculate h w correlation and then Holman you can use it to get k thermal conductivity, nu and alpha values for various temperatures. I expect you to do this home task for different values and check further because we are limited with lectures.

So, we may not be able to do all the problems here. So, I expect you to analyse based on whatever we discussed. Thank you.