Renewable Energy Engineering: Solar, Wind and Biomass Energy Systems
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Lecture - 4
Practice Problems_ Part II

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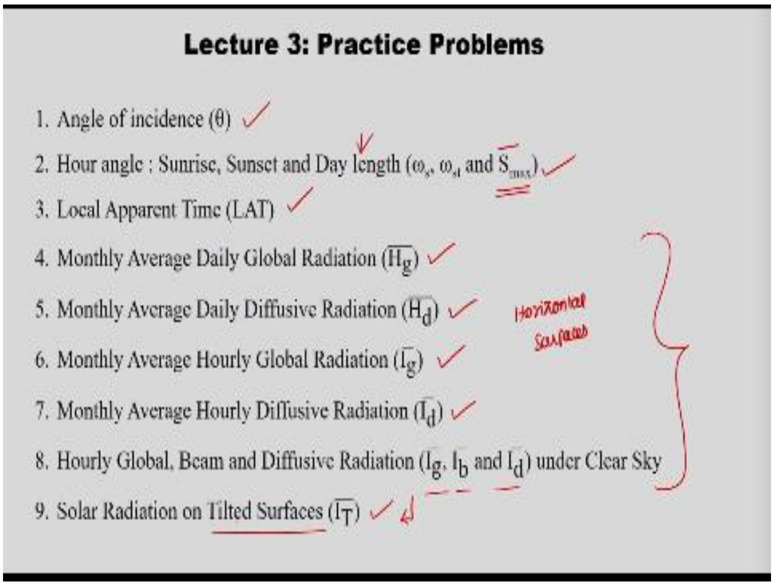

Good morning everyone. So, in yesterday's lecture, we were to calculate these 9 values angle of incidence; sunrise, sunset hour angle and day length; local apparent time; monthly average of daily and hourly global and diffusive radiation and then hourly global, beam and diffusive radiation under clear sky and solar radiation or tilted surface. So, we could calculate till here. So, monthly average hourly global radiation.

So, remember till now, we have calculated only for horizontal surfaces. As we told you earlier, the best method is to measure the solar radiation values using equipment actual data. If not available, we can use the similarity between 2 locations and try to calculate the solar radiation values for particular places. So, even that is also not possible then we use normally the correlations proposed by various researchers.

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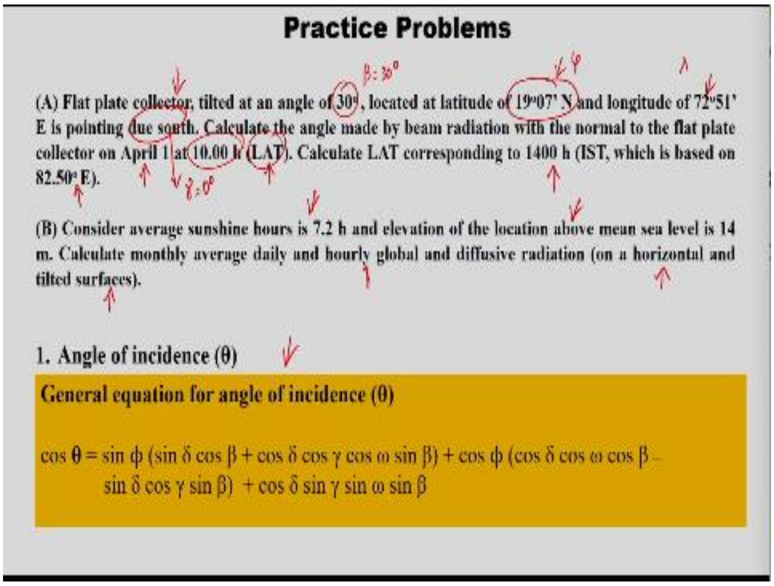

So, our problem had 2 parts. The first part is we supposed to calculate angle of incidence. So, that we have reviewed. So, why we need the angle of incidence value and then we also learn to calculate local apparent time corresponding to Indian Standard Time. Then the second part of the problem is for the average sunshine hours of 7.2 hour and the elevation of the location about main sea level is 14 meter, we were calculated the monthly average daily and hourly global and diffusive radiation. That was our second part of the problem.

Here we are going to calculate for tilted surfaces as well. So, while discussing the problem, we have also seen some of the concepts behind calculating each radiation values. So, now, we will directly go to what we suppose to calculate and where we stopped yesterday. So, I think we stopped here.

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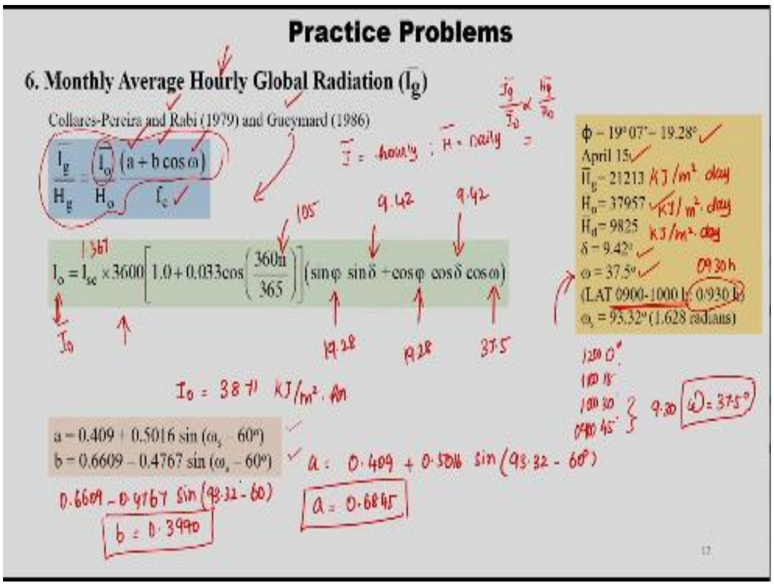

So, we calculated monthly average hourly global radiation, so, using the correlation proposed by Collares-Pereira and Rabi and Guevmard. So, here we calculated the constant values a, b and f c using that we could get the relation between this is I, is always hourly. So, H is for daily. So, both if you want to take monthly average that bar comes. So, this is what we have done here.

In this formula, it is nothing but I g bar upon I 0 bar, which is equivalent to H g d bar, H 0 bar; not equivalent to it is proportional. So, that proportionality constant is hour the correction factor whatever we may call it or fitting constant, so, that is nothing but a + b cos omega upon F c. So, the first researcher Collares-Pereira and Rabi, so, they told that we can simply take a + b cos omega that is enough.

Then Guevmard said that there is another correction factor we suppose to include to match it with actual data. So, for that a and b is given here. So, here we use omega s which is for horizontal surface hour angle during sunrise or sunset.

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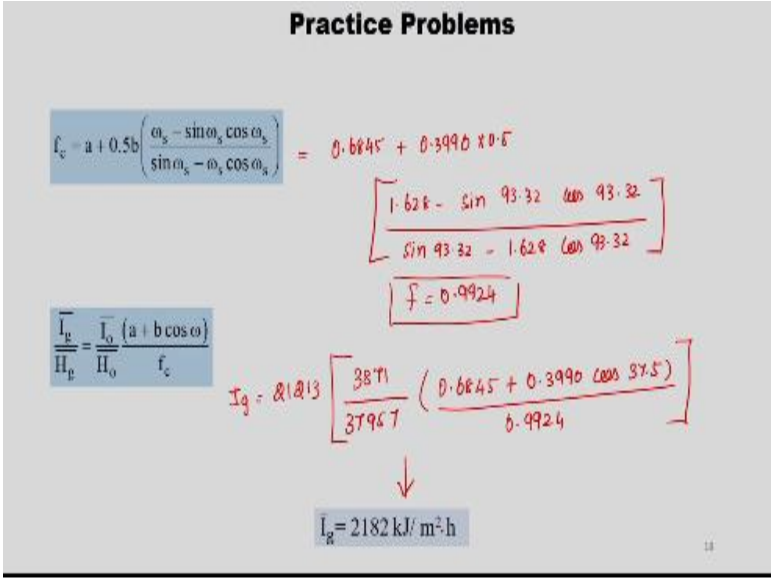

And I 0, I 0 bar we discussed yesterday and then we calculated f c as well, then from that value we predicted I g bar is nothing but 2182 kilojoules meter square hour.

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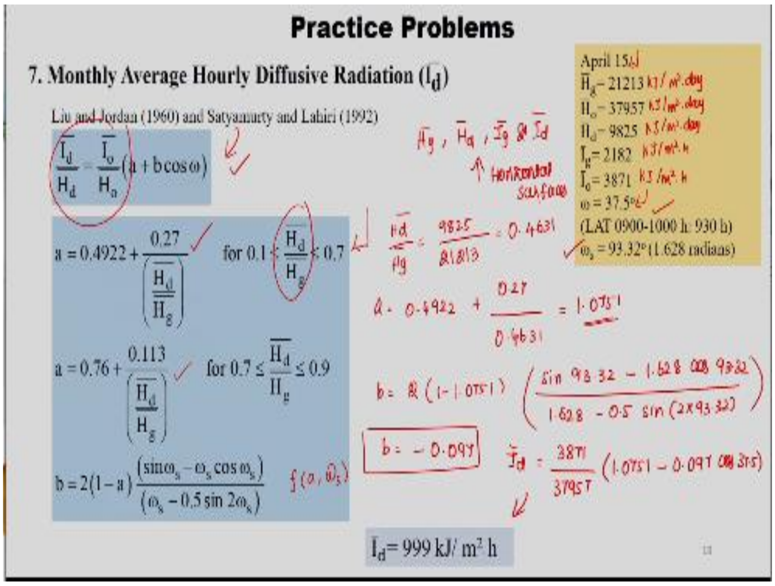

So, today we are going to see how to calculate monthly average hourly diffusive radiation I d bar. So, for that the proposed correlation is I d bar upon H d bar which is equal into I 0 bar upon H 0 bar into a + b cos omega. As I said earlier, the Leon and Jordaa said that, so, this is, this itself is enough. So, there will not be any proportionality constant is needed. That means proportionality constant is 1.

But again Satyamurty and Lahiri in 1992, they proposed this particular correlation I d upon H d bar which is equal into I 0 bar upon H 0 bar into a + b cos omega. So, for that they said the constant a can be calculated based on the ratio of H d upon H g. So, if this ratio comes out to be between 0.1 to 0.7, we supposed to use this particular formula. If the ratio is between 0.7 to 2.9, we supposed to use this formula for a and b is again function of, b is a function of a omega s, a and omega s.

So, omega s, we already have 93.32 degree which is nothing but 1.628 radians. And for the local apparent time or solar time of 9 to 10 hours, we calculated omega s 37.5 degree and I 0 we just calculated yesterday, I 0 is around 3871. So, that value is given here. So, kilojoules per meter square hour. Then I g value, we have calculated 2182 kilojoules per meter square hour.

Then h d value so, yesterday's calculation also we have chosen the H d value calculated from Modi et al. So, that we have given here. So, kilojoules per meter square day, because it is a daily average and H 0, we already calculated 37957 kilojoules meter square day and H g bar that also we have already calculated kilojoules meter square day. So, we have chosen April 15. Why? Because, we supposed to equate I 0 to I 0 bar. So, all the values are given.

So, we supposed to calculate what is the ratio between H d bar upon H g bar. So, H d is given us 9825 upon H g, which is nothing but 21213. So; which is turned out to be 0.4631. So, then we supposed to use the first formula, so, a is equal to 4922 + 0.27 upon 0.4631. So, this is 1.0751. So, remember when you calculate these values, we sometimes take 2 digits; sometimes take 3 digits.

So, in that way, when you calculate, there will be minor difference in this value. So, the way you calculate, for example, somebody calculate this ratio first and then add it. Somebody do it directly. And when you are using this value for further calculations, so, you may use the whole value instead of making it to 2 digits or 3 digits. So, in that way, there would be small variations. For example, if I am getting 999, you may get 1001 as well.

So, please do not worry about that. And then we supposed to calculate b. So, b is nothing but 2 into 1 - 1.0751 and sin omega s in degree 93.3 to - 1.628 which is omega s and cos 93.32 upon 1.628 - 0.5 sin 2 into 93.32. So, if you calculate, so, your b would turn around - 0.097. So, we calculated a; we calculated b then we go back and substitute in this value.

So, I d is one we supposed to calculate. So, I 0 that is 3871. H 0 that is 37957 and then a, a is 1.0751 + b - 0.097 cos omega is 37.5. So, if you calculate your I d is 999 kilojoules per meter square hour. So, we calculated monthly average hourly diffusive radiation, so, all these values. So, what is that H g, H d, I g and I d so, all are calculated for the horizontal surfaces.

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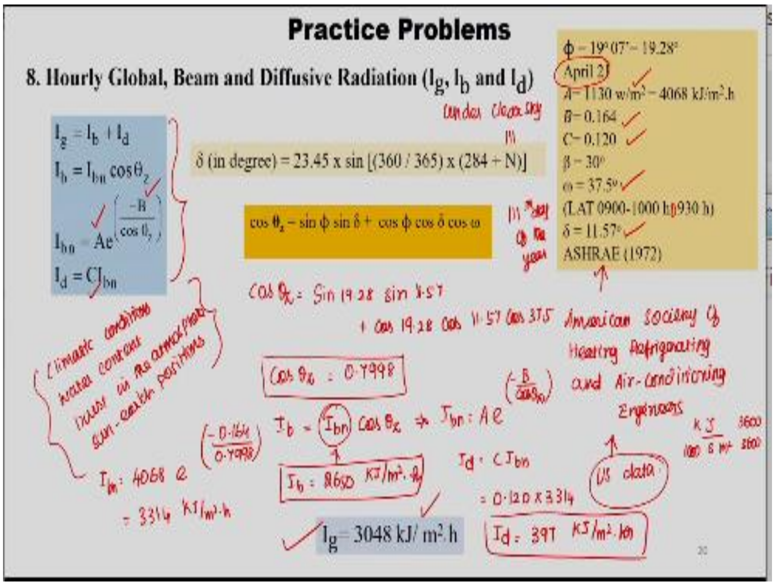

So, the next one is hourly global beam and diffusive radiation I g, I b and I d. So, this is under clear sky. So, how do we define this clear sky? Because nowadays we have sophisticated instruments to calculate the values exactly, but still these correlations were proposed long back, but here we are making ourself comfortable how to calculate, how to get these data. So, these data to calculate so, what are all the parameters we would be requiring.

If the actual measurement of solar radiation values are not available. So, this particular formula or model is proposed by ASHRAE. So, this is American Society of Heating Refrigerating and Air Conditioning Engineers. And also if we remember the ASHRAE, so, this particular model is proposed based on US data. So, to calculate here if you see we need A, B and C the constants.

So, here we have A, B, C. So, this is proposed for over a year. But it is for the year but each month will have different constants, throughout the year, the constant do not be same. Because we know the climatic conditions and the water vapour content because these constants are used to calculate beam radiation as well as diffusive radiation. So, the water vapour content and the dust in that atmosphere and sun and earth position because that also changes throughout the year.

So, all these 3 constants are function of all these things. So, because of that each month, they proposed different constants and also it is totally based on US data, but still we use this here to learn about how to predict the global radiation using their model. As I said earlier, so, this is for particular day. They have given in year April 21st these 3 constants are available A, B, C.

And if you see here a constant is nothing but flux watt per meter square. So, this, we supposed to convert into kilojoules meters square hour. So, in that case we suppose to convert. So, what does joule per second meter square so, we supposed to multiply and divide by 3600 to make it to joule meter square and then hour. And we suppose to calculate this as a kilojoules as well.

So, 4068 and we multiply and divide by 1000 as well. Because we supposed to get the values as kilo. So, we have to divide by 1000 as well. So, in that case, you would get 1130 would be converted into 4068 kilojoules meter square hour. So, B, C constants are unit less. So, that we do not bother about that. So, the beta value is not required at all here because we are still calculating for horizontal surface only and omega is 37.5.

So, lat we have taken us 930 hour, so, for that, the delta is 11.57. Why delta we supposed to calculate? So, now, it became April 21st. So, April 21st is nothing but 111th day of the year. So, we supposed to substitute 111 here, so, and then calculate delta. So, that is 11.57. And we would require here cos theta z. So, that is we still calculate for the same location. So, sin 19.28 and sin delta is 11.57 + cos 19.28 cos 11.57, omega is 37.5.

So, if you calculate, so, your cos theta z is nothing but 0.7998. So, from this we will calculate the hourly beam radiation I b, which is equivalent to I bn cos theta z. So, I bn is nothing but the beam radiation in the direction of sun rays. So, I bn we supposed to calculate again we need I bn for this. So, I bn we are going to calculate using the ASHRAE model. So, A e power - b upon cos theta z.

So, it is nothing but exponential decay of the beam radiation . So, we have here A is 4068 that is A and then e to the power - B, - 0.164 so, cos theta z is 0.7998. So, if we calculate this is I bn, so, this is becoming 3314 kilojoules per meter square hour. So, if we substitute I bn value here, so, I b turned out to be 2650 kilojoules per meter square hour. So, I b we calculated. I d is nothing but C into I bn.

So, I bn value we already have. C is nothing but 0.120. I bn is nothing but 3314. So, how much I d we get is 397 kilojoules per meter square hour. So, if we add I b and I d then what you get is I g. I g is 3048 kilojoules meter square hour. So, here we used the US data. So, what we can do is we can get the actual data of Indian climate and compare both. How much I b value we get for a particular location and how much I d value we get.

So, there, based on the US data we are getting beam radiation is high and diffusive radiation is as much as low but based on the Indian climate maybe diffusive radiation would be high and beam radiation would be low but they compensate each other and probably we might be getting global radiation is same around. So, that we can always compare and check whether that particular model would be able to calculate this global beam and diffusive radiation under clear sky.

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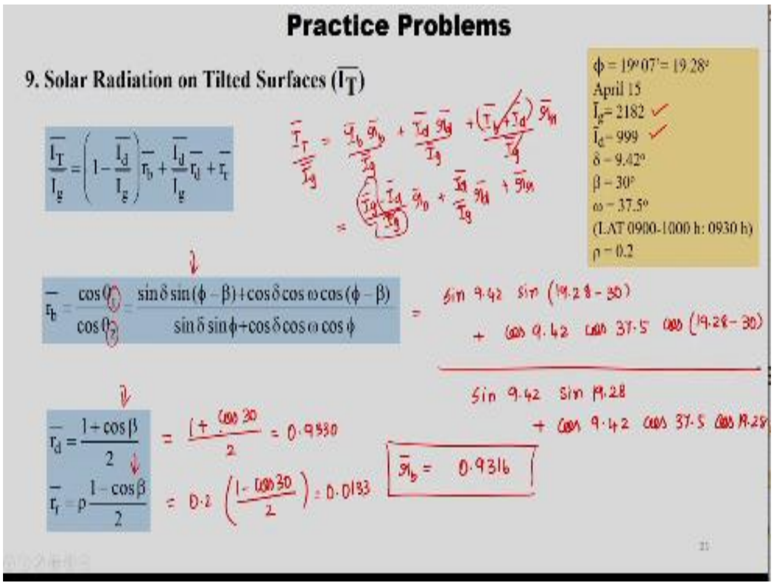

Solar radiation on tilted surfaces: So, here the formula is total radiation which is falling on tilted surface which is equivalent to I b, r b, I d r d + I g which is nothing but I b, I d, r r. This, we have seen in the lectures already. So, this is divided by I g throughout because we already have the values of I g as well as I d that is global as well as diffusive radiation. So, we wanted to convert in terms of I d and I g.

So, this is I b. I b can be written as I g - I d upon I g. So, this becomes 1. So, 1 - I d into r b + I d upon I g into r d. So, I b + I d which is nothing but I g. So, this becomes r r. So, to calculate that we would require that conversion factor alliterated factor so, r b, r d and r r. So, r b is as we discussed in the lecture, it is cos theta i upon cos theta z, so i is nothing but angle of incidence. Z is nothing but Zenith angle.

So, we have all the parameters, sin delta is 9.42 sin 19.28 - 30 + cos 9.42 cos 37.5 cos 19.28 - 30. So, this is cos theta i and cos theta z is nothing but, sin of 9.42 sin 19.28 + cos 9.42 cos 37.5 cos 19.28. So, if you calculate this value, it is coming around 0.9316. So, we have calculated r b. So, this bar refers to monthly average and r d and r r is very straightforward 1 + cos 30 upon 2 which is nothing but 0.9330.

And r r is row which is 0.2 taken for concrete surfaces into 1 - cos 30 upon 2 which is 0.0133. So, we have r d ready, r r ready, r b ready.

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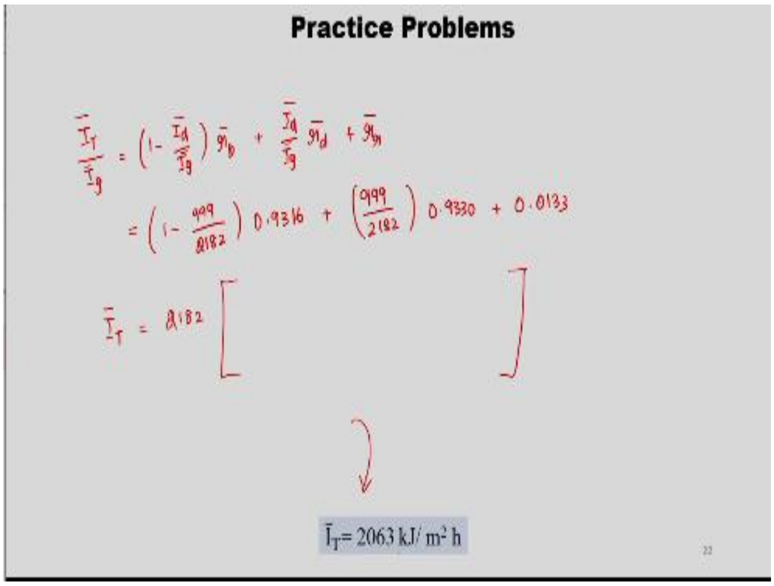

So, then we supposed to substitute in the equation I T upon I g is equivalent to 1 – I d upon I g into r b + I d upon I g into r d + r r. So, this particular values 1 – I d upon I g. So, this value is given here. So, I d is 999; I g is 2182. r b, we calculated as 0.9316 plus I d is 999 upon 2182, r d, we calculated as 0. 9330 + 0.0133. So, from this we calculate I T as I g. I g is nothing but 2182 into this total value.

So, if you calculate, your I T is coming around 2063 kilojoules per meter square hour. So, these values also calculated as kilojoules per meter square hour. So, this is also kilojoules per meter square hour.

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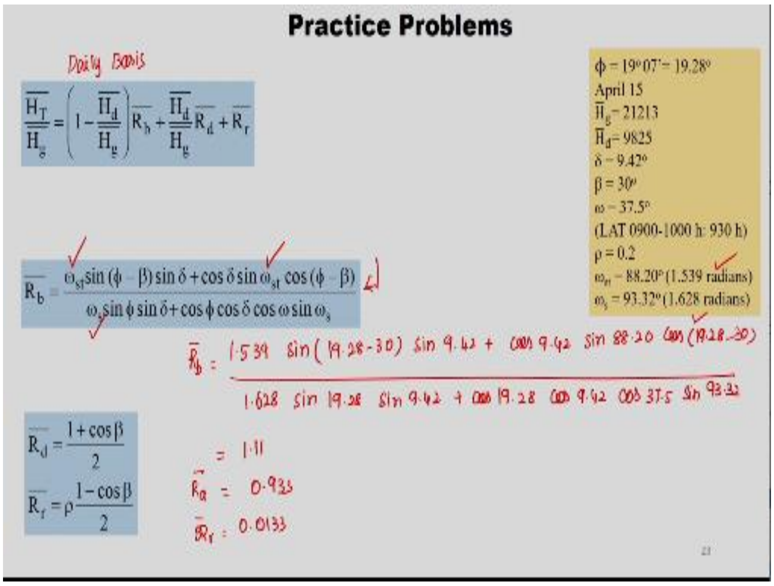

So, the same way, you can also use the correlations to calculate on a day basis which is daily basis as well. So, daily basis also formula is same. H T upon H g into 1 - H d upon H g r b + H d upon H g r d and r r. So, but if you see the way we calculate r b that is tilt factor for a beam radiation that is different for calculating on daily basis. So, here we have that omega st also in place and omega s also is in place.

So, that we have already so, for omega st is 88.20 and omega s is 93.32. So, we supposed to substitute here. So, r b is here, omega st we supposed to substitute in radians. So, 1.539 sin 19.28 - 30 sin. Our delta is **(( )) (24:24)** similar. So, April 15th so, 9.42 + cos 9.42 sin omega st 88.20 cos 19.28 – beta, beta is 30 upon omega s which is 93.32. This is degree but we supposed to substitute in radians 1.628 sin 19.28 sin 9.42 + cos 19.28 cos 9.42 cos 37.5 sin omega z 93.3.

So, if you calculate, your r b is coming as 1.11. r d is same whatever we calculated previously 0.933, r r is also same which is 0.0133.

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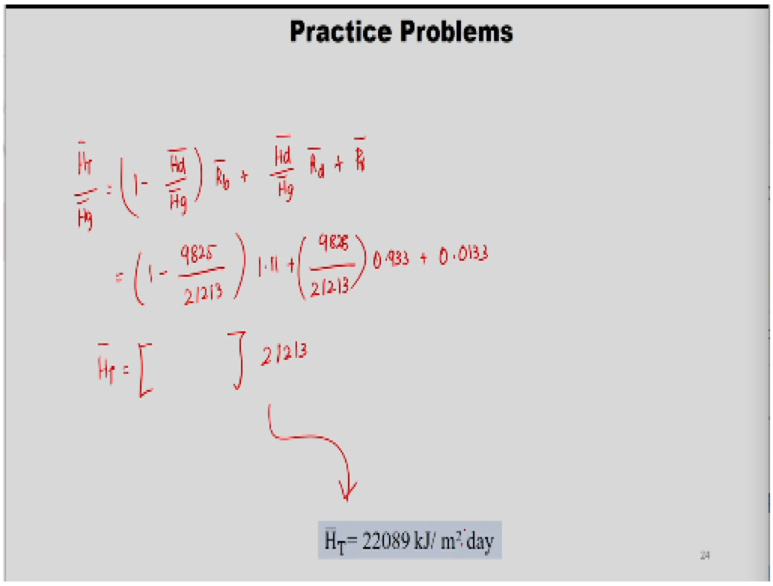

So, then we supposed to calculate H T bar upon H g bar, which is 1 - H d bar H g bar into r b bar + H d bar H g bar r d bar + r r bar. So, here we have H g and H d in place. So, H d is 9825. H g is 21213 into r b what we calculated is 1.11, H d is 9825 2123 into r d, r d is 0.933 + 0.0133. So, how much H d you would get is, this total into H g. H g is 21213. So, H d what you get is 22089 kilojoules per meter square day.

So, this is total flux falling on daily average basis. So, in this way you would be able to calculate the H d that is total flux falling on a tilted collector which is the total radiation of beam diffusive and reflective radiation. So, that is all. So, we learned in this particular lecture to calculate various solar radiation values using correlations and formula presented in past 2 classes. So, here we have listed out the references.

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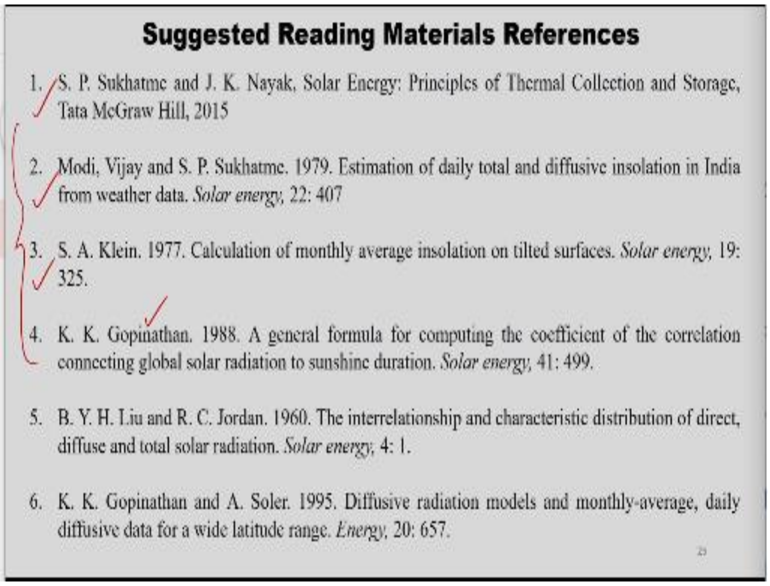

So, these four references were used yesterday. So, today we used Liu and Jordan.

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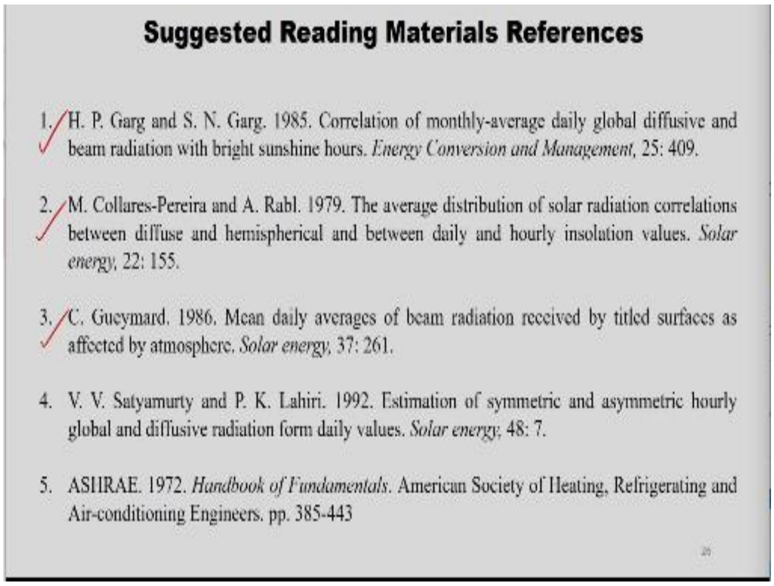

So, another journal paper and Satyamurty and Lahiri we used and ASHRAE which is Handbook of fundamentals, that particular model to calculate the beam global and diffusive radiation under clear sky. So, these are suggested references and all the formula and the correlations, you would get from Sukhatmc and Nayak, solar energy principles of thermal collection and storage. Thank you.