Thermal Operations in Food Process Engineering: Theory and Applications
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Lecture - 38
Heat Transfer by Radiation (Contd.)

Good morning. So, you were continuing addition heat transfer. Now we are in the lecture number 38. So, it should be Radiation Heat Transfer continued, 'right'. So, we have seen that when there are 2 parallel plates and there was a shield in between then what is the radiation due to that shield whether that shield is really reducing the heat transfer rate or not that we have seen and with problem also we have found out that the reduction is substantial around 10 to 12 times or even more depending on the values of emissivities, 'right'.

We have also seen that if that was for parallel plate, but we also have seen for cylindrical or spherical shaped objects or surfaces where the surface area was varying that was A_1, A_2 and A_3, 'right' 2 surfaces A_1 and A_2. So, in between the shield was given A_3 and with that the expression for the heat transfer rate that we have determined, 'right'. Now, again look a let us look into some problem. So, that we are confident about the development, 'right'.

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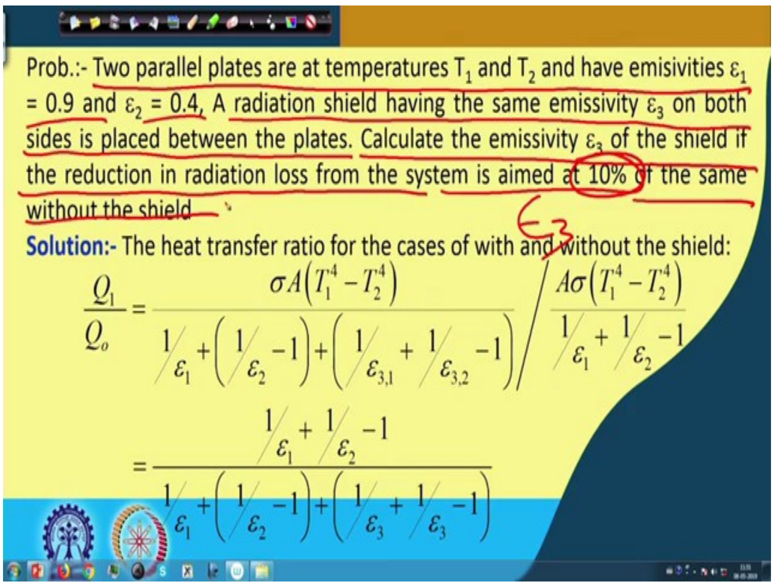

So, problem is like this that 2 parallel plates at temperatures T_1 and T_2, at temperatures T_1 and T_2 and have emissivities ε_1 and ε_2 where ε_1 is 0.9 and ε_2 is 0.4. A radiation shield having the same emissivity has epsilon 3 on both sides is placed between the plates. So, ε_3 is not given, 'right'. Calculate the emissivity ε_3 of the shield if the reduction in radiation loss from the system is aimed at 10% of the same without the shield, 'right'.

So, now what we are saying that yes we have 2 parallel plates and we have put one shield in between and the emissivities of these 2 parallel plates are known. And the emissivity of the shield is not known, but it is said that the emissivity on both the sides are same of the shield that is the assumption.

That the shield has on the both the sides the same emissivities and the parallel plates emissivities are given. Now, it is required that by putting that shield you want to reduce the heat loss by 10%, 'right' heat loss to 10% not by 10% heat loss to 10% you want to bring down, 'right' and if that then what should be the value of emissivity of the shield, 'right' this is the problem.

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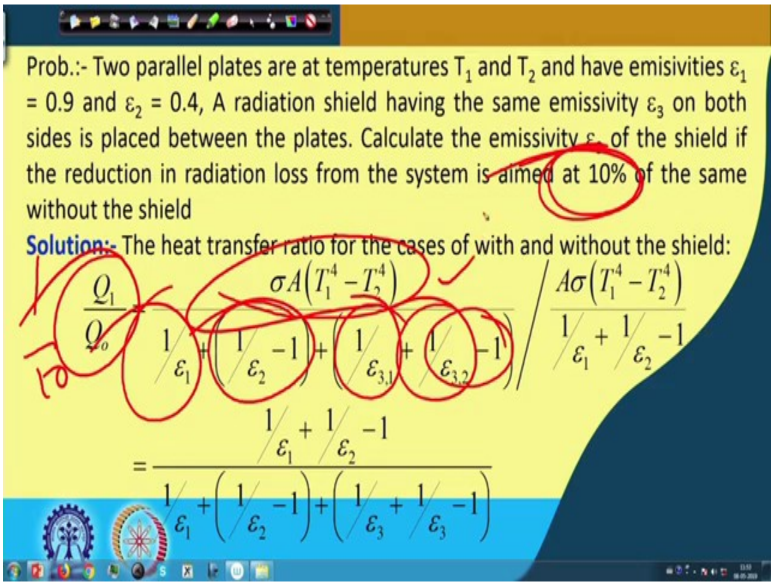

So, the solution of it if you want to see that this means the ratio Q_1 is to Q_o that is with and without shield that should be 110, 'right' that is what we have been said that the ratio of Q_1 to Q_o should be 10% or 110, 'right'. So, the ratio if we put

$$\frac{\sigma A\left(T_1^4 - T_2^4\right)}{\frac{1}{\varepsilon_1} + \left(\frac{1}{\varepsilon_2} - 1\right) + \left(\frac{1}{\varepsilon_{3,1}} + \frac{1}{\varepsilon_{3,2}} - 1\right)}$$ this is with shield and without shield is $$\frac{\sigma A\left(T_1^4 - T_2^4\right)}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1}.$$

Here only one thing we are achieving that the area of the parallel plates and that of the shield are same, ’right’.

Area of the parallel plates and that of the shield are same this is what we are assuming, ’right’. Then this ratio comes down to because your this part goes up with this part, ’right’ and then only we have this denominator goes on the top $1/\varepsilon_1 + 1/\varepsilon_2 - 1$.

And , the new that this denominator that remains that is $1/\varepsilon_1 + 1/\varepsilon_2 - 1 + 1/\varepsilon_3 + 1/\varepsilon_3 - 1$ this should be $1/\varepsilon_{1,3}$ and $1/\varepsilon_{3,2}$, ’right’. Typically it should be $1/\varepsilon_{3,1}$ and $1/\varepsilon_{1,3}$ the typical should be 1, 3 and that is 3, 2. So, that ε_3 is not known we have to find out.

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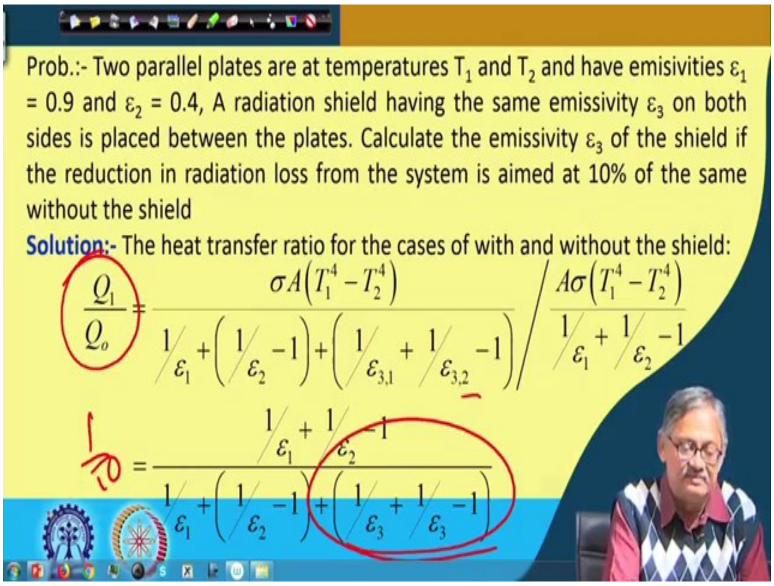

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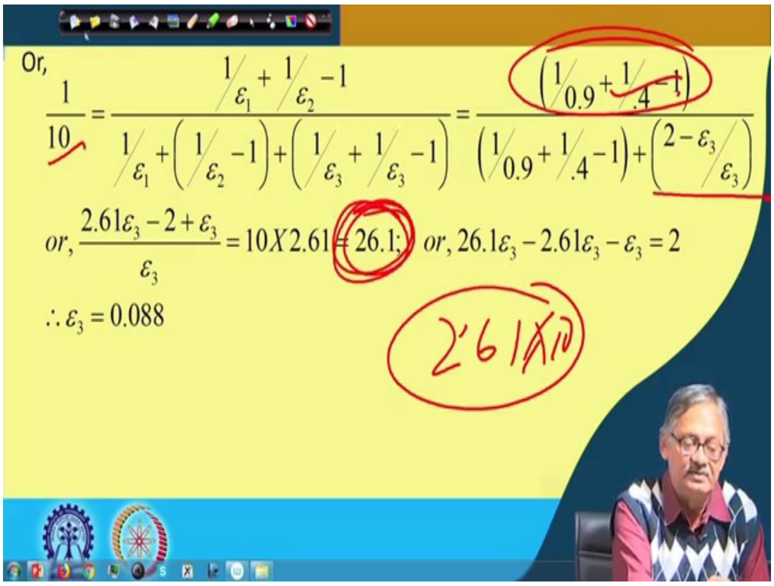

And, this ratio is 1/10, 'right'. If this be true then let us solve it and find out that this is nothing, but 1/10 is $[1/\varepsilon_1 + 1/\varepsilon_2 - 1] / [1/\varepsilon_1 + (1/\varepsilon_2 - 1) + (1/\varepsilon_3 + 1/\varepsilon_3 - 1)]$ if we simplify that as $1/\varepsilon_3 - 1$ that is the values are given of ε_1 and 2 (1/0.9 + 1/0.4 – 1) here also 1/0.9 + 1/0.4 – 1 and this is nothing, but $(2 - \varepsilon_1) / \varepsilon_3$ sorry $(2 - \varepsilon_3) / \varepsilon_3$, 'right'.

So, this on simplification we can write that 2.61 because this value has become 26.1, 'right'. This value has become 26.1 so, 26.1 because that is here, no this value has become 2.61 not 26 2.61. So, 2.61 × 10 ,'right' so, this into this 2.61 × 10 that is 26.1.

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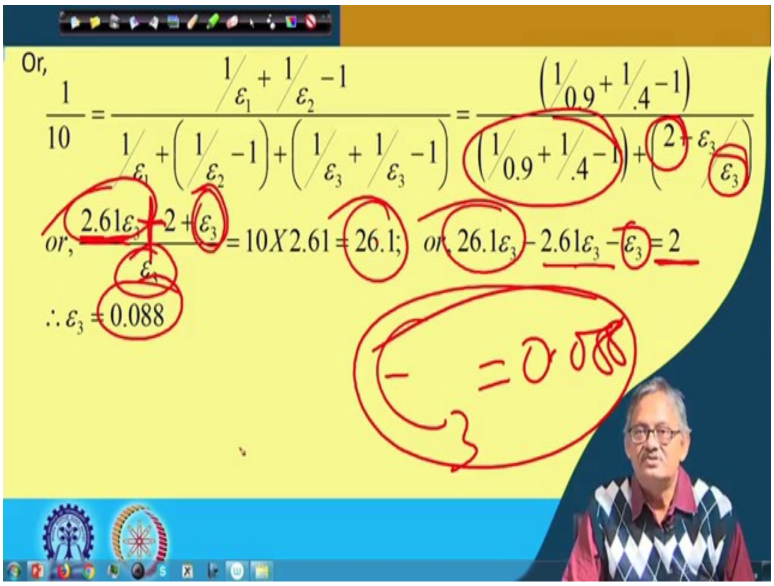

And, this side when we are taken here this is 2.61. So, 2.61 ε_3 2.61 ε_3 and this is not minus this should be plus. So, plus 2 2 - ε_3, 'right' is 26.1, 'right'. So, we can write 26.1 this is over ε_3 26.1 ε_3, 'right' and 26.1 ε_3 yeah 26.1 ε_3 - 2.61 this 2.61 ε_3 and this is plus ε_3. So, minus ε_3 this is equals to 2.

So, it is plus not minus, 'right'. So, this becomes the equal to 26 minus 2.6 minus 1 26 minus 2.61 minus 1. So, 2 by that is ε_3 and that is coming 0.088. So, the values of ε_3 is 0.088, 'right'. If this emissivity value is so low then you can bring down the lost or by addition to it is without the shield whatever is the loss, you can bring down it to $1/10^{th}$ of that, 'right'.

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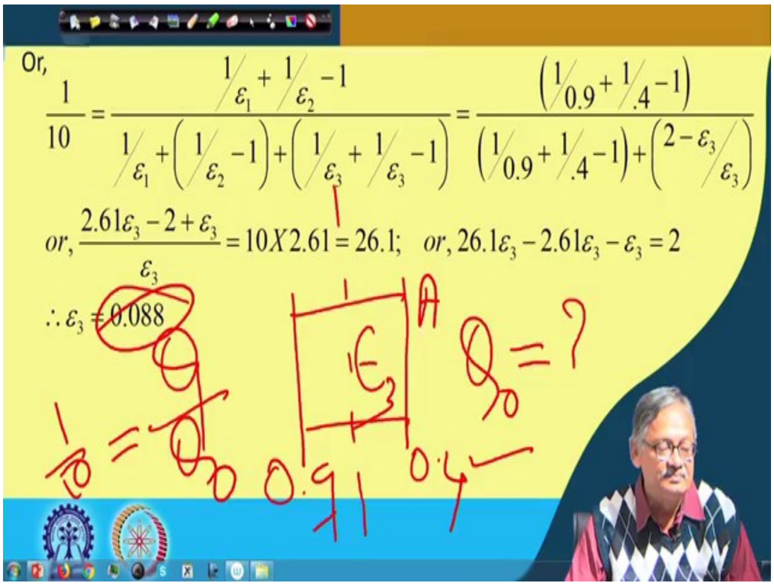

So, that means, in other words if we had these two shields which has one emissivity of 0.9 and the other emissivity of 0.4 if this is there then whatever heat loss Q was there without the shield the value of that we do not know. But, now you are asked that 2 tear shield of the same area all 3 have the same area A ,'right' and put a shield or bring the same area where the Q shield normally we are expressing is at Q_1 ,'right'

So, this Q shield over Q_o that must be equals to 1/10. So, these two values are known what is the value of this ε_3 this is the problem which we have emphasized and we have solved it that the value comes to 0.088 ε,'right'. So that means, you see that the reduction in radiation by putting the shield can be so, drastic,'right'.

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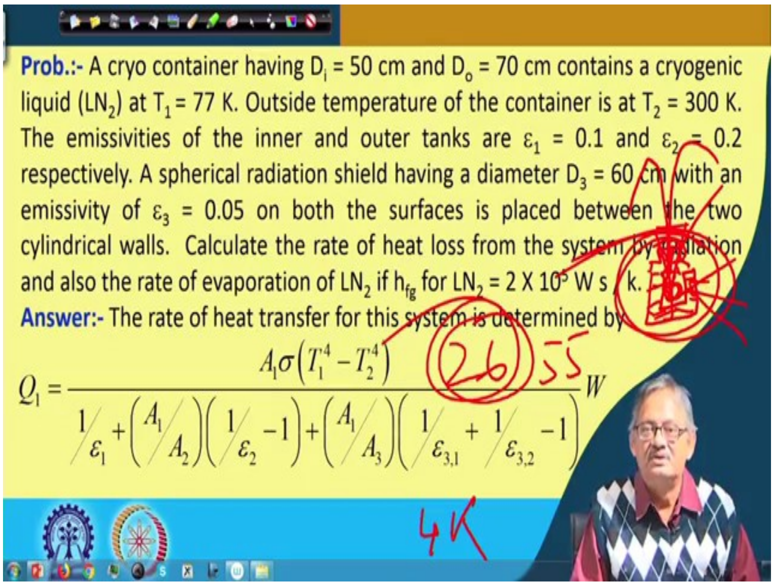

Next let us look into another problem. This is a really handy problem that a cryo container. Now in this regard let me also give a little I do not say it is preamble a little information more that cryo containers are like that which are normally double walled, 'right', like this they are double walled they have a neck here actually should have been like this much more. Sorry.

So, actually it should have been like this, 'right'. So, there is 11 1 1 stopper cork here, 'right'. There is 1 stopper cork here and this double wall is may be under vacuum or some inserting material. So, inside there are cryogen. Now cryogen means say liquid air, liquid helium, liquid nitrogen, liquid oxygen all these are called cryogen, 'right', temperature of who which are may be 150 °C - 170, 180, 190, 200 or helium temperature is 4 K helium temperature is 4 K.

So, they are kept under this kind of double wall system like the thermo plus you have a similar one, but with much much better insulation ,'right'. So, these things are to be kept inside. This is the solution of that kind of problem ,'right'. So, you have a double wall container and you want to put a shield in between such that the radiation heat loss is minimum such that the because of the heat loss heat which is coming in the liquid is boil off and then that comes out of this ,'right'.

So, that comes of this and this is what if you keep may be normally we handle say 26 litre container or 55 litre container. So, say if it is a 26 litre container by 3 4 days or even

1 week if we keep this liquid unused with that cork on the top there is a movable and if you are keeping it like that. So, by 7 days this boils off and it becomes empty, ’right’. That means a continuous heat is being flown, ’right’. So, this is the similar problem I get the little preamble of that. So, that understanding becomes more and easier.

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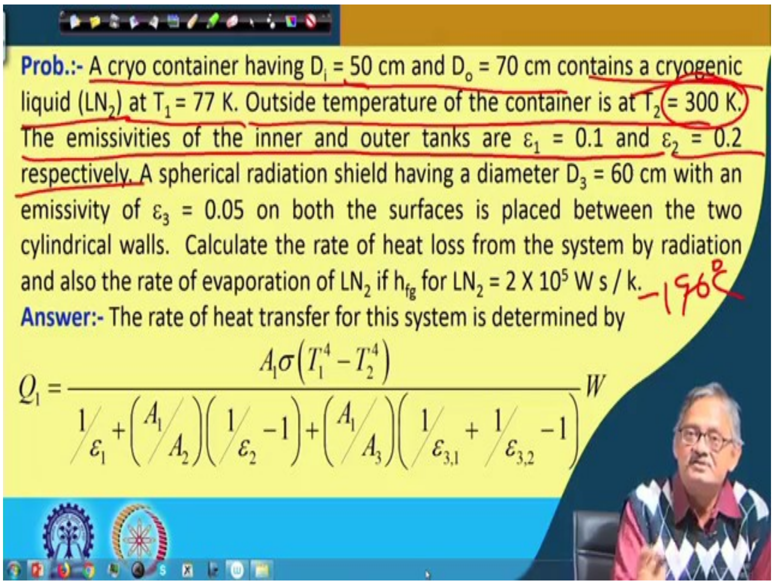

So, a cryo container having diameter D_i 50 cm and D_o 70 cm continuing a cryogenic liquid such as liquid nitrogen at temperature 77 K, ’right’ 77 K means somewhere minus 196 °C ,’right’. So, you think such a low boiling liquid is inside. Outside temperature of the container that is atmospheric temperature T_2 is 300 K, ’right’ normal 300 K means somewhat 27 °C that is a room temperature, ’right’.

The emissivities of the inner and outer tanks ε_1 is 0.1 and ε_2 is 0.2 respectively, ’right’. So, this is the similar problem as we had given you like this ,’right’; so, similar problem. So, now, what do you need? You are now a spherical radiation shield having a diameter D_3 is equals to 60 cm with an emissivity of ε_3 equals to 0.05 on both the surfaces. So, new this one is put which has emissivity ε_3 on both sides this phase also that phase also, ’right’.

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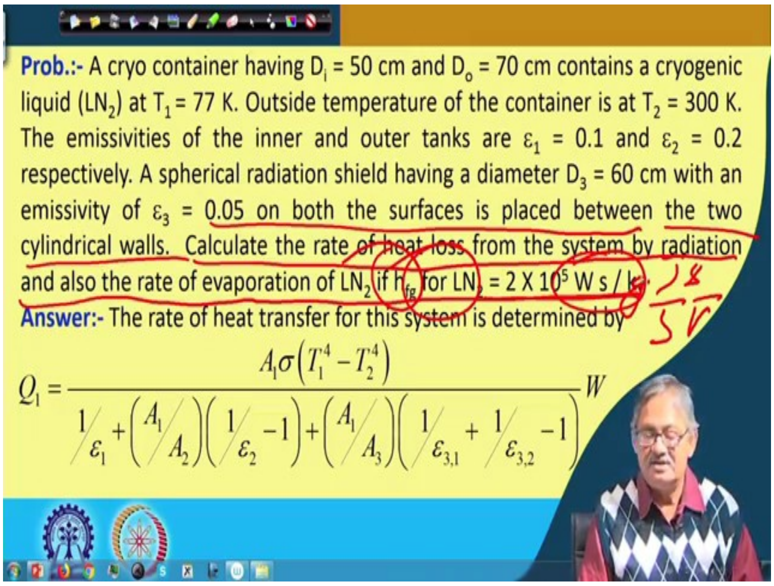

So, if that is put that the 0.05 on both the surfaces is placed between the 2 cylindrical walls. Calculate the rate of heat loss from the system by radiation and also calculate the rate of evaporation of the cryogen that is liquid nitrogen if h_fg that is latent heat of vaporization is for say liquid nitrogen is 2 × 10^5 W.s/K W.s/K means watt is J/s and there is another second per not Kelvin this is kg sorry that g is missing, 'right' g is missing somewhat type of mistake.

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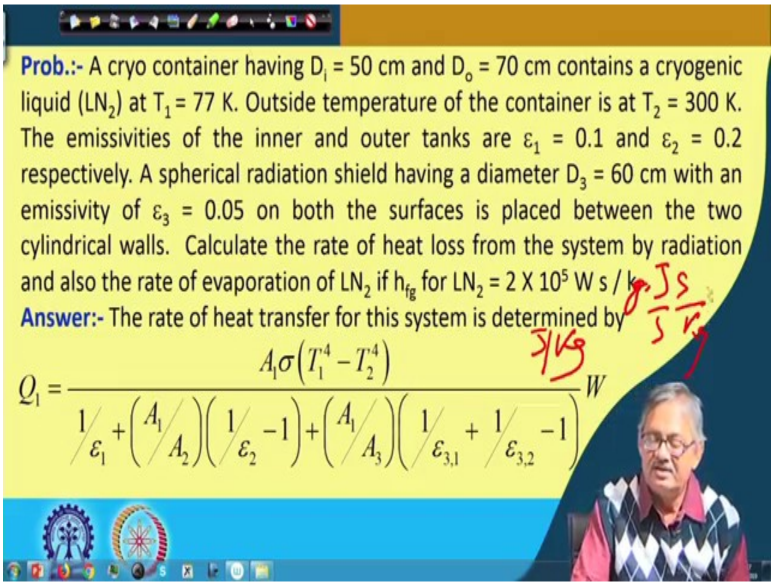

So, it should be kg not k W.s/kg means what are joules per second and you have a second. So, it is J/kg normally that is the thing J/kg, 'right'. So, 200 kJ, 'right' 200 kJ/ kg is the latent heat of vaporization of liquid nitrogen, 'right'.

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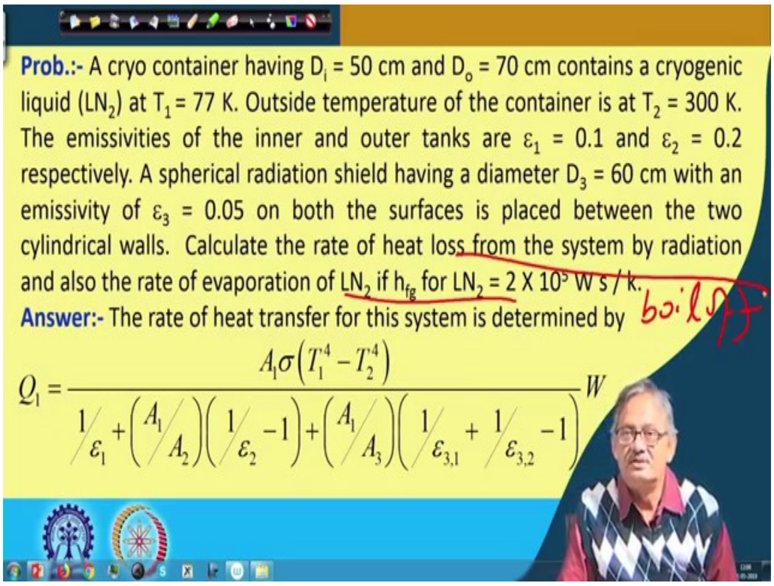

So, what we need to do we what do we need to find out. We have to find out that the heat loss from the system by radiation after giving the shield and we have to find out even after giving the shield what is the; this is called boil off, 'right' this is called boil off. So, what is the boil off of the cryogen that is liquid nitrogen, 'right'. So, rapidly we go through the problem once again a cryo container having D_i 50 cm and D_o 70 cm continuing a cryogenic liquid that is liquid nitrogen at temperature T_1 77 K outside temperature of the container is at T_2 equal to 300 K.

The emissivities of the inner and outer tanks are ε_1 = 0.1 and ε_2 = 0.2 respectively. Spherical radiation shield having a diameter D_3 = 6 cm with an emissivity of ε_3 = 0.05 on both the sides or both the surfaces is placed between the 2 cylindrical walls.

Calculate the rate of heat loss from the system by radiation and also calculate that calculate is not written also calculate the rate of evaporation of liquid nitrogen if h_fg that is latent heat of vaporization of liquid nitrogen given is 2 $\times 10^5$ W.s/kg, 'right'. So, to solve it let us take that radiation heat loss with shield and that is Q_1 equals to A_1 σ (T_1^4 - T_2^4) because diameters are different D_i is 50 D_o is 70 and D_3 is 60, 'right' 3 diameters are there. So, the areas are also different A_1, A_2 and A_3 they are all different, 'right'.

So, we are we need to find out areas and the expression for Q is Q_1 equals to A_1 σ (T_1^4-T_2^4) / 1/ σ 1 / $\mathcal{E}_1$ + (A_1 / A_2) × (1 / $\mathcal{E}_2$ – 1) + (A_1 / A_3) × (1 / $\mathcal{E}_{3,1}$ +1 / $\mathcal{E}_{3,2}$ – 1)+ 1 / $\mathcal{E}_{3,2}$ – 1 so, much Watt, 'right'.

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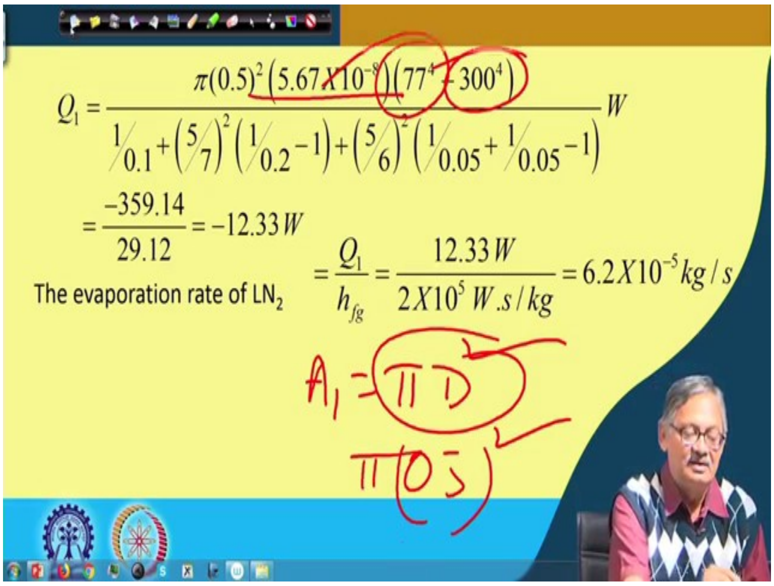

So, if we now find out the solution that Q_1 is nothing, but the areas first A_1 and A_2. We have to find out, 'right'. So, diameters are given. So, area is $A_1 = \pi D^2$, 'right'. So, πD^2 if that is there then we find out A_1 to be $\pi \times 0.5^2$,'right' and σ is 5.67×10^{-8} Stefan Boltzmann constant and T_1 is 77 K. So, 77^4 and T_2 is atmospheric temperature that is 300 K so, 300^4.

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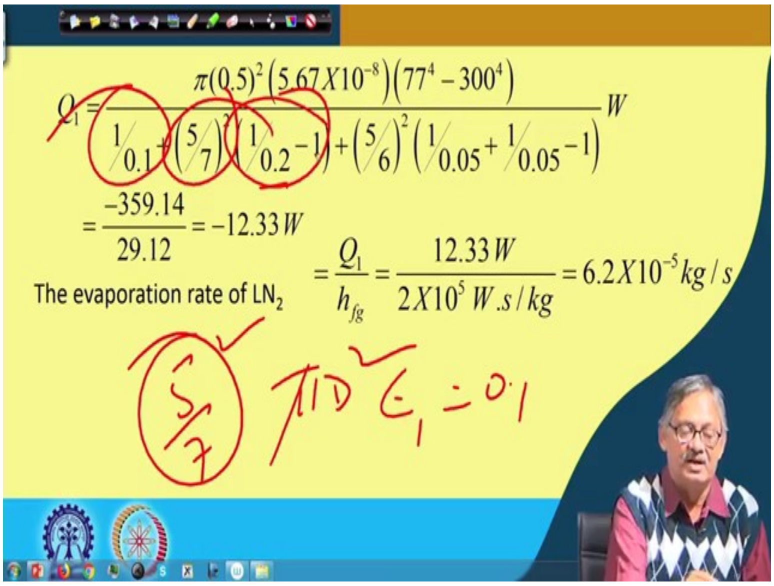

Divided by ε_1 given is 1/0.1 ε_1 is 0.1, 'right' and + $5/7^2$ $5/7^2$ that is A_1/A_2 A_1/A_2 since it is πD^2. So, we have π going out. So, it was A_1 was 5 and A_2 was 7. So, 5/ 7 square or A_1 was whatever 50 and 70, 'right' 50 and 70. So, 0 goes out π $(5/7)^2$, 'right' and into 1/ ε_2, i.e., 0.2 – 1 that is this part.

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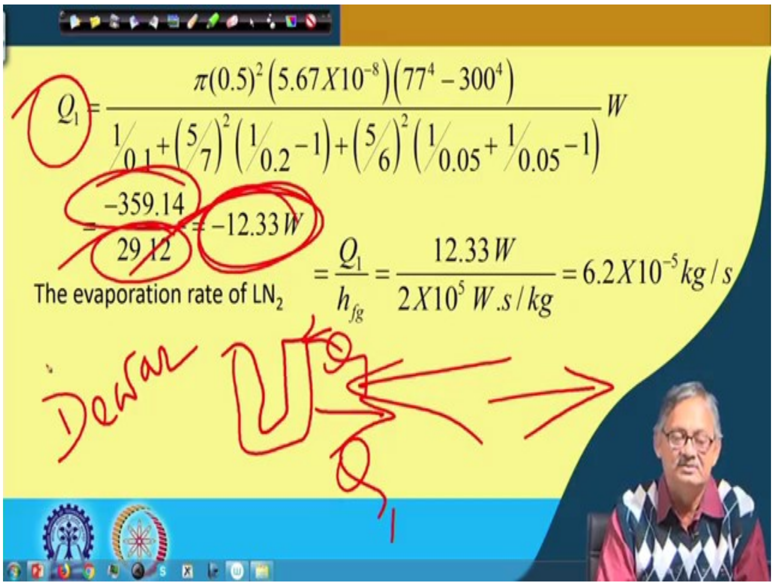

This part is A_1/A_3, 'right' A_1 is 50 and A_3 was 60 cm. So, that becomes 5 by 6 ratio square ,'right' and this times 1/0.005 that is the ε_3 + 1 by point 0 0 0.05 not point 00 1/0.05 + 1/0.05 – 1, 'right'. So, this comes equals to minus 359.14 / 29.12, 'right'. So, this is minus 12.33 Watt, 'right'. So, that Q is minus 12.33 watt; that means, heat is not going out heat is coming in, 'right'. So, we have this. This is called dewar. These are called dewar d e w a r. So, in the dewar the heat is not going out Q_1 is not going out Q_1 is coming in, 'right' that is why it is the negative 12.33 Watt, 'right' so.

We have 12.33 watts of the Q which is penetrating into the dewar. So, what is the evaporation rate then we know h_fg and h_fg was 2×10^5 W.s/kg here we have corrected per kg there it was if you remember only small k was there g did not come in. So, Q_1 / h_fg is this is 12.33 and the h_fg is 2 2×10^5.

So, that is 6.2×10^{-5}; so, much kg/s, 'right'. This Watt, this Watt goes out this second remains and this kg goes on the numerator. So, kg per second 6.2×10^{-5} kg/s; so, you convert it into per day we will see it is also some kg.

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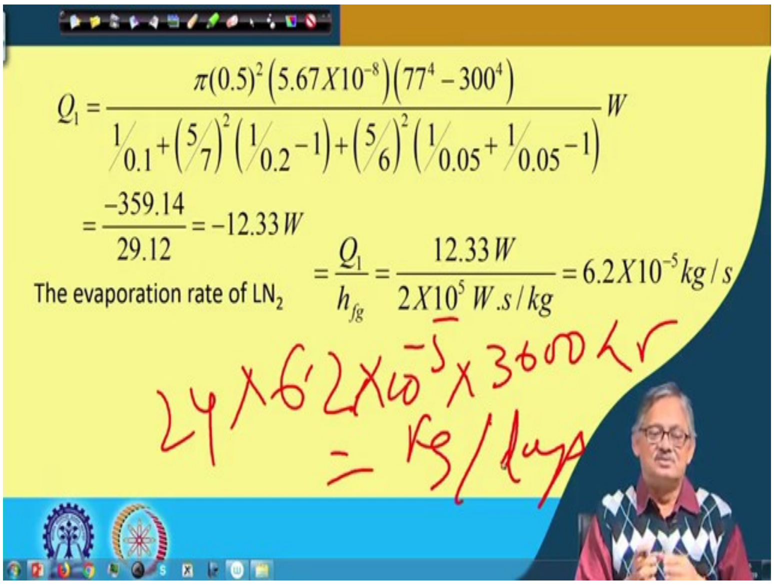

So, that becomes 6.2×10^{-5}, 'right' into 3,600 is hour into 24. So, that becomes so much kg/day, 'right' and you will see that per day it will be losing some 8 to 10 kg or even more or 7 to 8 kg or even more. So, that is the loss of from the dewar. This is a great example which is a online example or practical example we are giving, 'right'.

So, with this we come to the end of the topic perhaps radiation, 'right'. So, we come to the end of the topic radiation. So, you do problems and solution and wish you all the best.

Thank you.