Chemical Reaction Engineering 1 (Homogenous Reactors)
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Lecture No 60
Direct use of RTD to predict conversion (Macro and Micro-fluid as well as Macro and Micro-mixing Concept) Part 3

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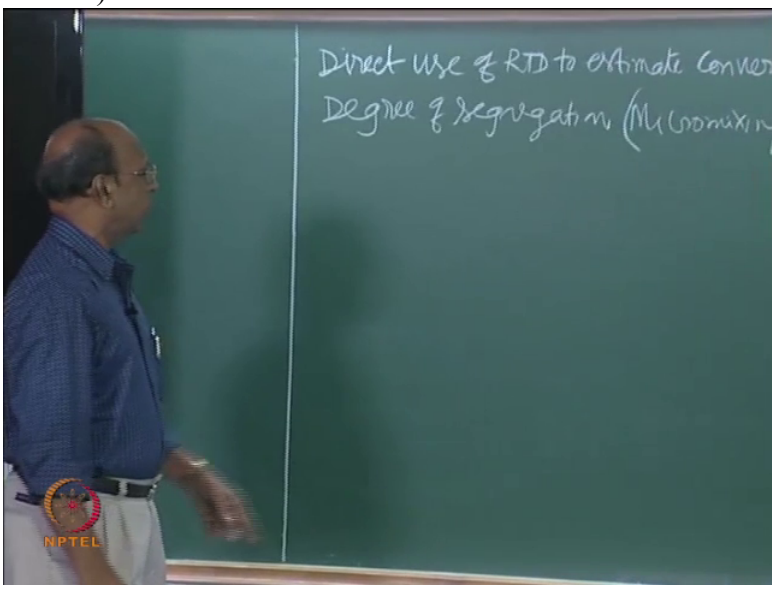

So degree of segregation or micro mixing, this is what what we have been discussing yesterday, and we also for, yeah and then we took batch reactor and

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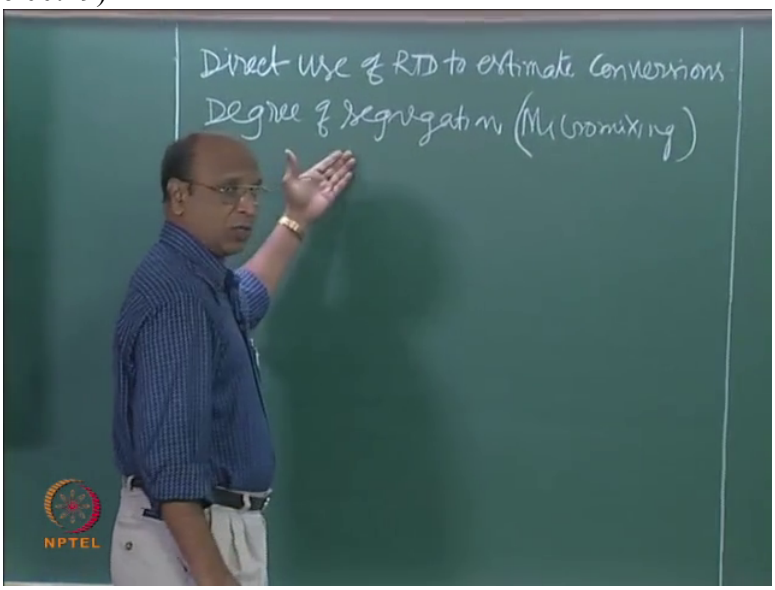

also ideal plug flow reactor and then we found that whether you have micro fluid

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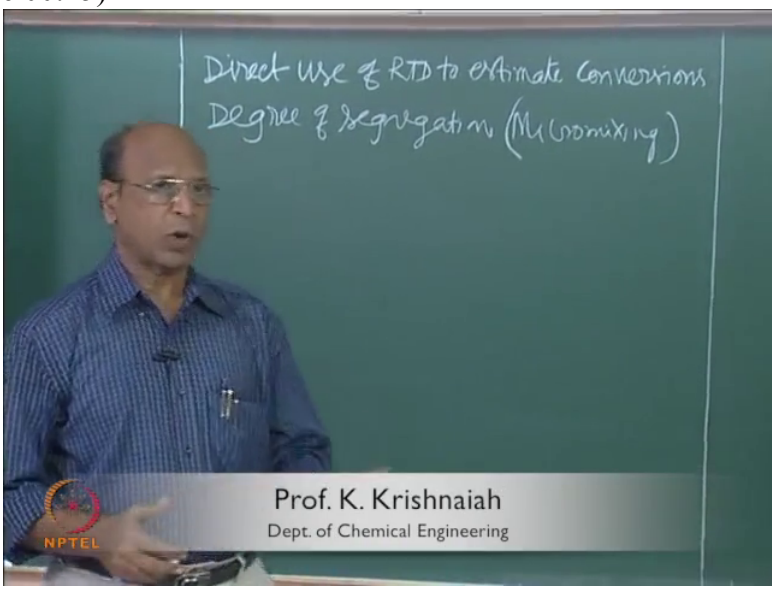

or macro fluid there is no, yeah same conversion. There is no difference.

So whenever you have batch reactor and plug flow reactor, if you have micro fluid or macro fluid, does not matter, right. And then we went to mixed flow reactor and then we again started thinking about micro fluid and macro fluid.

Micro fluid is the one which we have already done and we know the equation for first order, second order or even third order if I have mixed flow reactor, micro fluid. Micro fluid is the one with individual molecules and all that. Ok, so that is the one.

And then we went to macro fluid. Macro fluid, it behaves differently because the molecules are not communicating with each other. Each packet only stays some time and the conversion in that packet depends on how much time it has spent inside the reactor, and R T D gives me that information, how many packets, how much time, right?

How many packets means it is a fraction of material between time t and t plus delta t is E t d t, in that E t d t I have let us say 10 percent of the fraction. In that 10 percent of the fraction I will have may be millions of packets. Because packet size are very, very small. I am saying this big but it is never, right? So that is why.

Then we wrote the segregated fluid design expression. Ok, what was that? This is C A bar by C A naught, this is averaging only, zero to infinity, C A by C A naught batch E t d t, right. So

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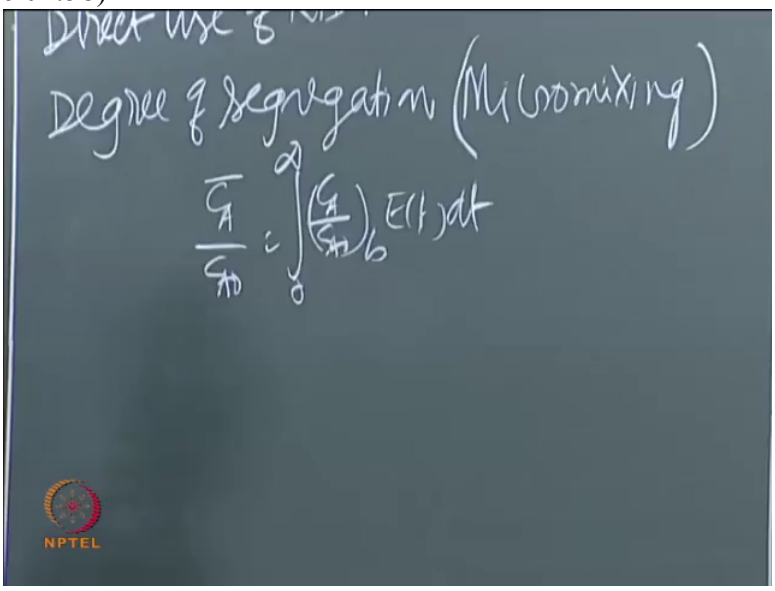

this is C A by C A naught batch is the one which I can imagine my packets are batch reactors and those batch reactors are spending some time, and that time will be given by E t d t, so correspondingly now I can find out this, you know the conversion in a segregated fluid, Ok.

So micro fluid, ideal P F R, I mean ideal M F R, ideal P F R all that you know how to write the balance. That is also no problem. Good. So then for second order reaction we have developed an equation for n equal to 2, I just gave that integral expression before leaving, yeah this is 1 by t bar correct, t bar M. t bar or t bar M, I wrote?

(Professor – student conversation starts)

Student: t bar

Professor: Ok, t bar, Ok so then zero to infinity and for second order reaction, you know, yeah.

(Professor – student conversation ends)

But for E t it is an ideal M F R, Ok. This is for M F R. P F R and all that we said there is no change between micro fluid and macro fluid. That is why for only this we are deriving equation n equal to 2. So this is e power minus t by t bar divided by 1 plus k C A naught t into d t, right.

So this cannot be integrated. So only thing is

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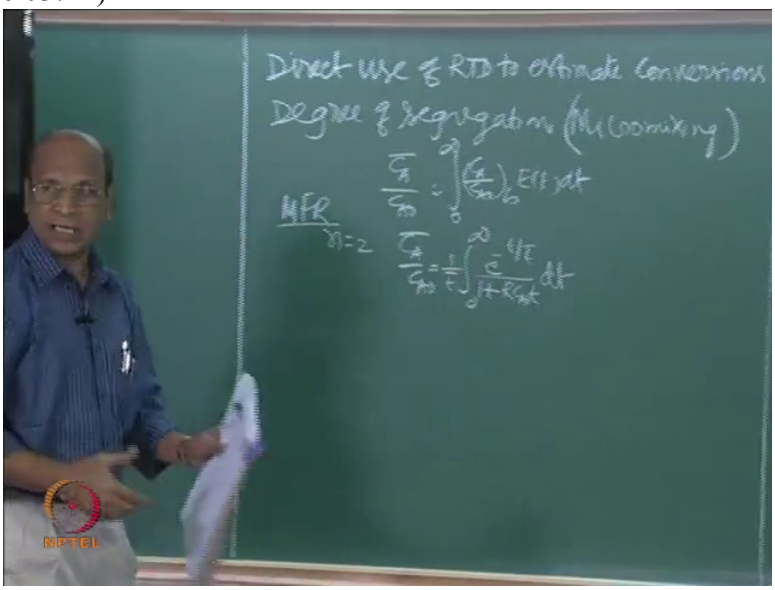

it has to be transformed into the form of exponential integral, Ok. So exponential integral is defined as e of i, x, we have already done once is x to infinity, I may have minus t by t d t.

If I am able to convert this format into this format,

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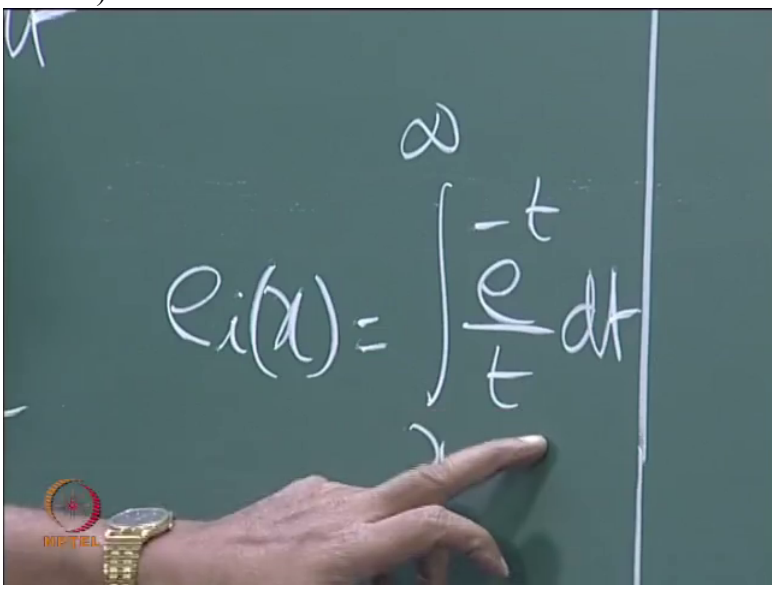

right then I have an exponential integral and depending on the value of x there, because e i x, right, if the x equal to 2, that means the value depends only on lower limit.

If x equal to 2 I will go to my mathematical tables and then see what is the value of x equal to 2, right and the latest edition of Levenspiel, he also given you know, expansion, x equal, I

mean you can substitute for any x and then calculate. He has given an equation also in that, right? Ok. Otherwise tables are available. Then you can just go and read that.

So now our idea is to convert this into this format. So the first thing what we do here is let alpha equal to 1 by k C A naught t bar. In fact this is inverse of Damkohler number, right, yeah. So this is the one.

Now,

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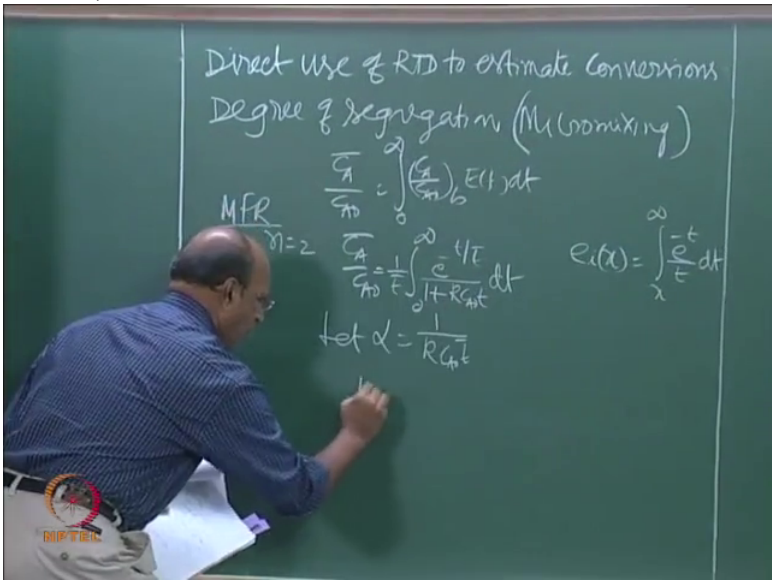

now let us say that we have k C A naught t, this also can be written as 1 plus k C A naught t bar by theta where theta equal to yeah, t by t bar,

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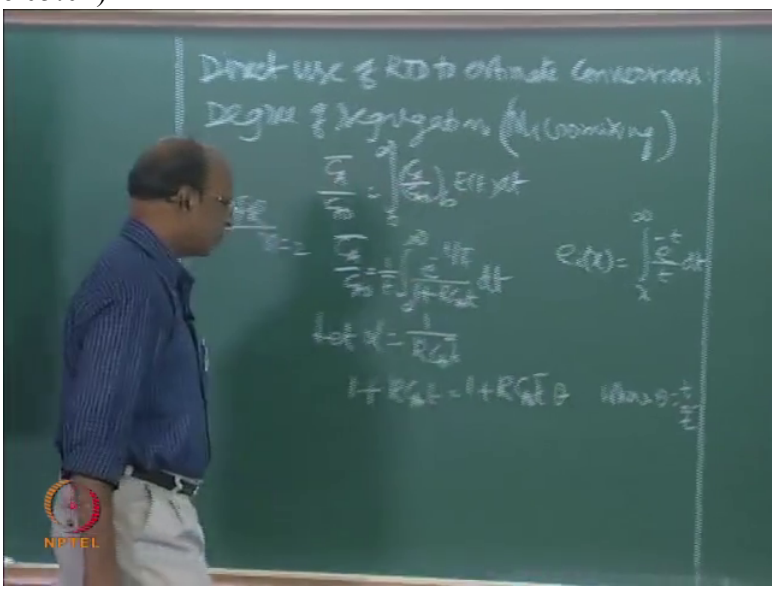

Ok. So I just multiplied and divided by t by

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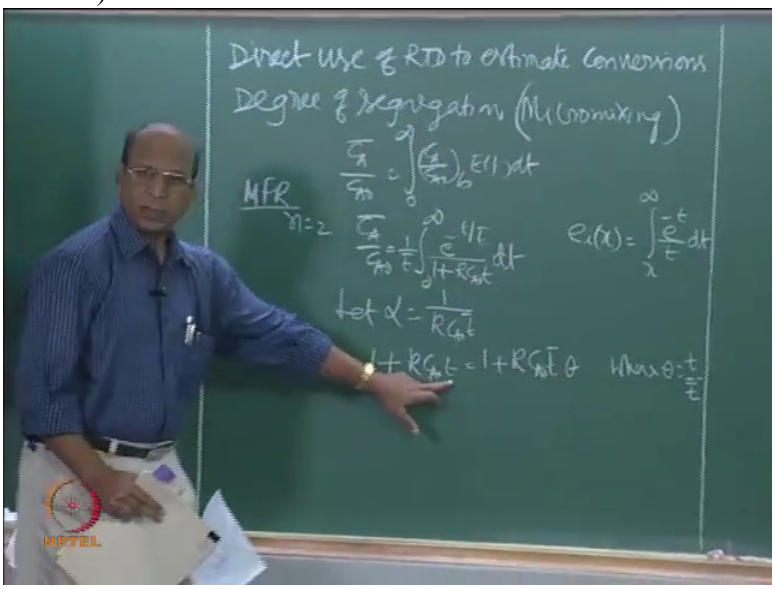

t bar, divided by t bar and multiplied by t bar so that became theta, right.

So now this equation is also nothing but 1 plus theta by alpha, correct no? Alpha is this definition and that is also equal to alpha plus theta by alpha, Ok. So did I give any equation numbers earlier; for this?

(Professor – student conversation starts)

Student: No

Professor: Then I think you put this one 1, this one 2,

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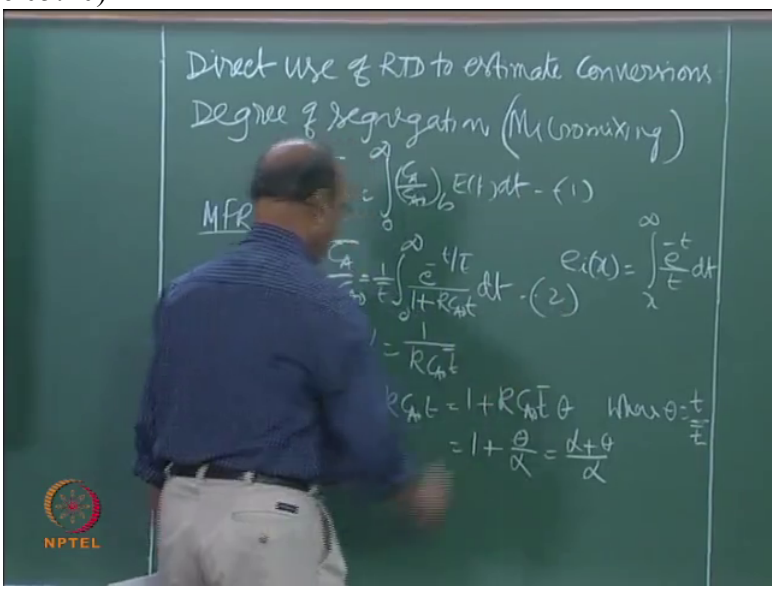

and this one 3, Ok good.

(Professor – student conversation ends)

So now let us also take, because now I have to convert, you know. This entire thing is now to convert this equation into exponential integral. That is why, right. So now let us also take alpha plus theta as alpha plus t by t bar. And now let us differentiate this. Ok, Ok, Ok, also equal to x.

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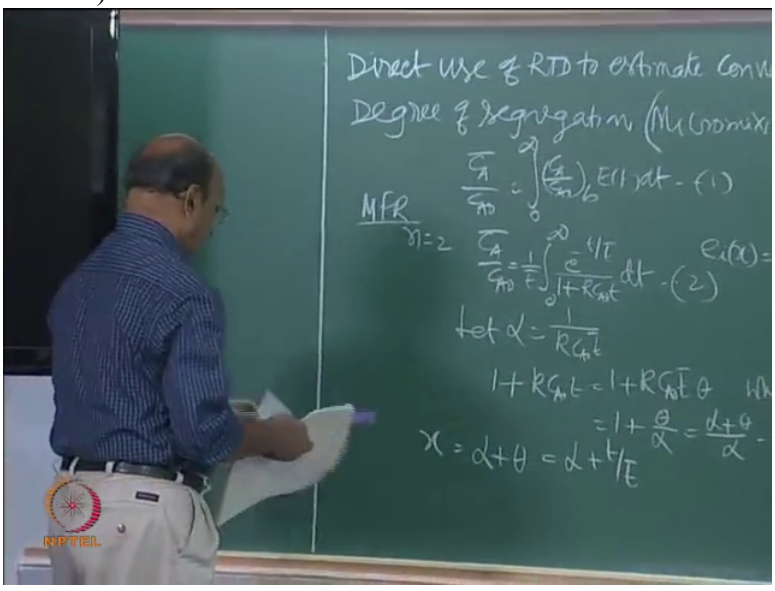

And let me differentiate this, so if I differentiate this, d of alpha theta equal to how much, yeah this also, d of alpha, alpha is a constant, please remember, correct no? It is a constant

value. When I do that what I get here is d theta by, Ok I will write here, d theta, this is equation number 4,

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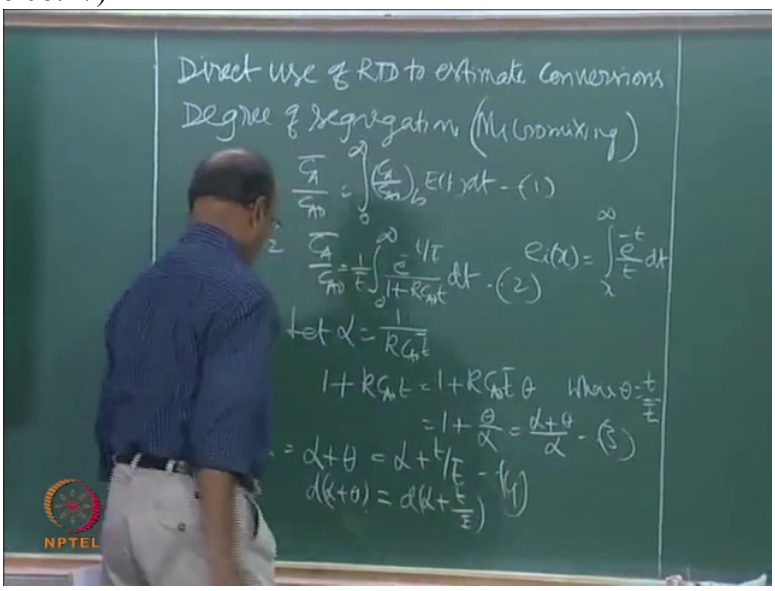

yeah d theta equal to, yeah, d theta equal to d t by t bar, right. Good.

So now substitute all these values here, alpha, Ok, so substituting equation 3, 4 and 5, this if take as 5,

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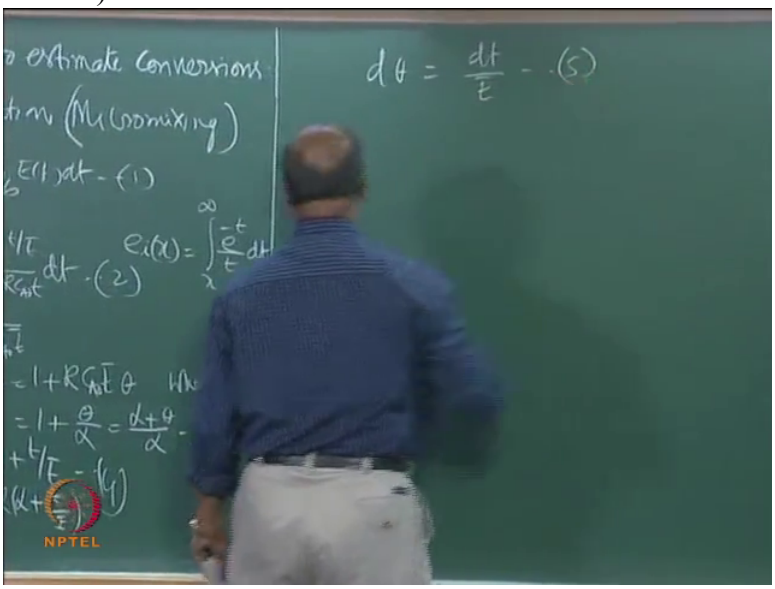

what do you get? Can someone quickly tell? C A bar by C A naught. Substituting equation 3, 4, 5 in 2;

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3, 4, 5 in 2.

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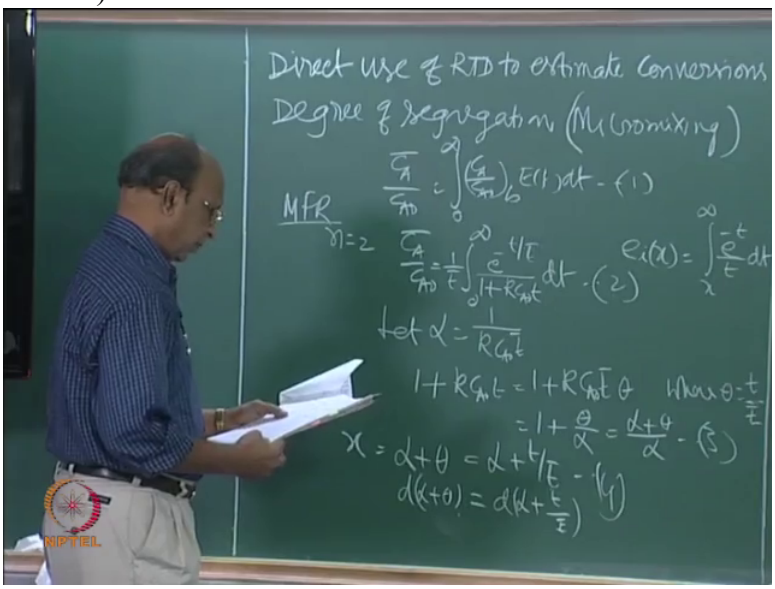

Got it?

(Professor – student conversation starts)

Student: I did not bring the notes

Professor: You did not bring your notes? You have no? Ok. But yesterday also we have told here. Yeah, someone quickly? Ok I will write. May be slightly difficult for you.

(Professor – student conversation ends)

Let me write that, you know. I have alpha, e alpha e power minus alpha theta divided by alpha theta into d of alpha theta. I added here e power alpha

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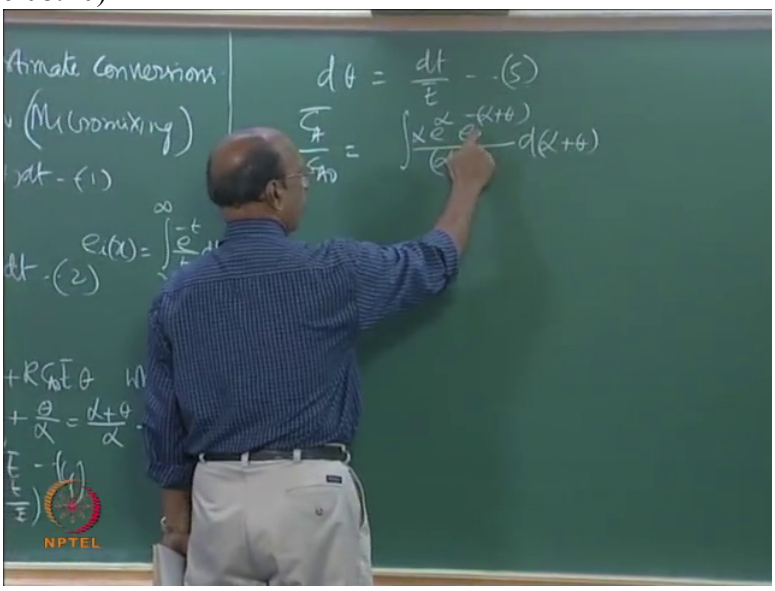

and minus alpha because here I have only

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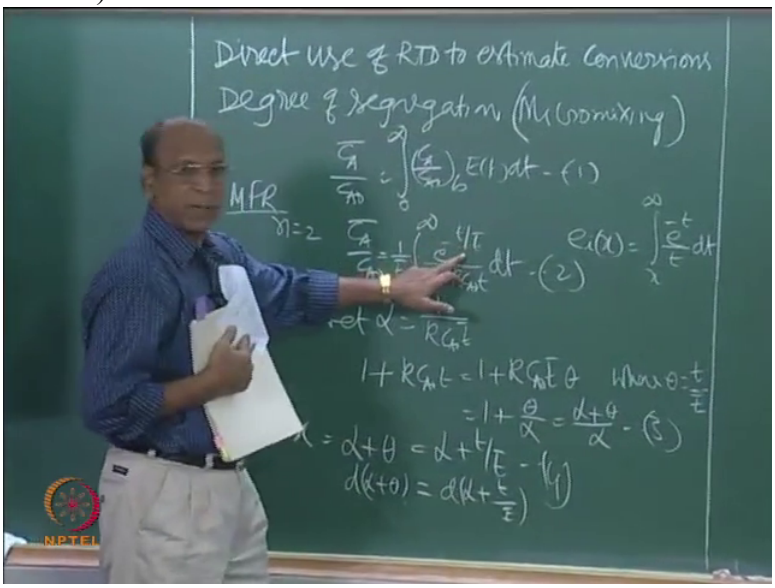

t by t bar, right? So I multiplied by, t by t bar is nothing but theta, that is no problem. e power minus theta. Then I added minus alpha and also multiplied by plus alpha so that that will become 1, right? So that manipulation.

Why all that manipulation? Only to get this. Now I also told you alpha theta is equal to x. And alpha, e power alpha is it constant?

(Professor – student conversation starts)

Student: e power alpha

Professor: Yeah, so they will come out.

(Professor – student conversation ends)

So I will have here, alpha e power alpha, limits I will just put there, then we have, this is minus x by x d x.

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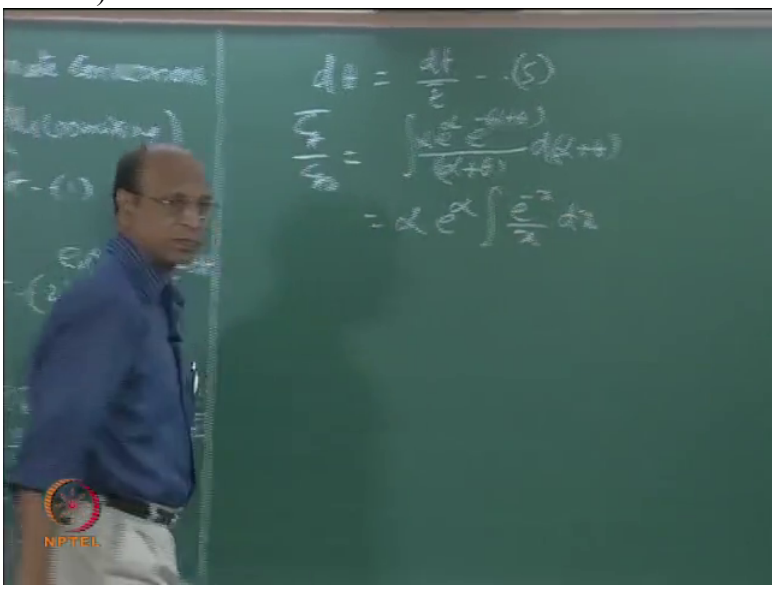

Ok. now taking here the lower limit, when t equal to zero,

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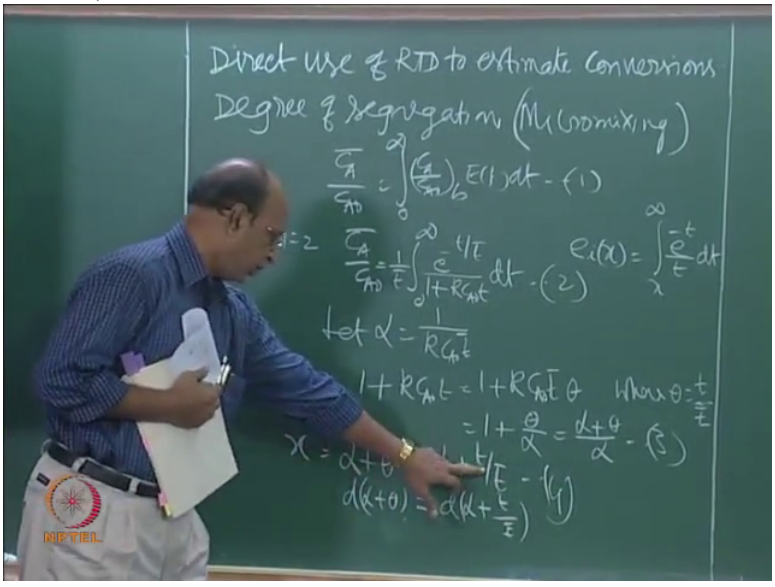

theta also zero.

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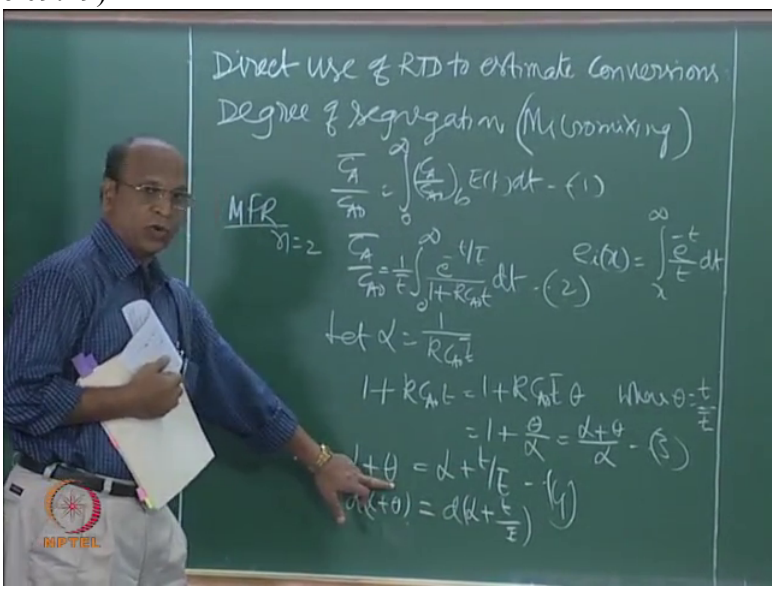

Then that will be, lower limit will be alpha. Lower limit will be alpha.

Upper limit anyway theta infinity also Ok, so now we do not have to take this one. When theta equal to zero, x equal to alpha. Because everything is written in terms of x, no, 0:09:39.7.

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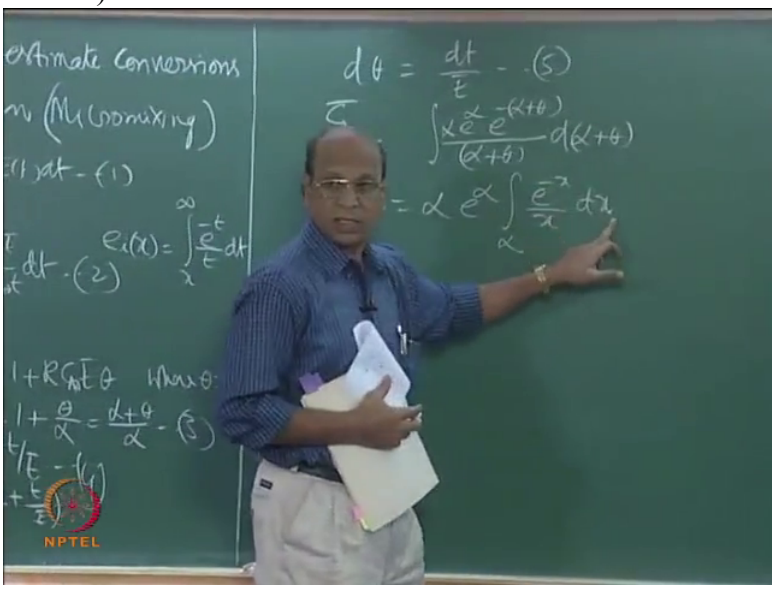

x, right. So when theta equal to,

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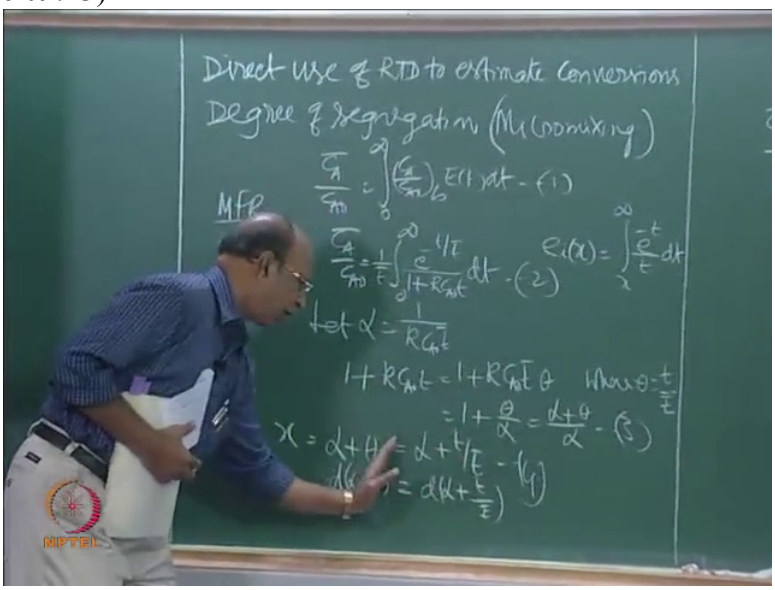

we need not worry about that one, now. Theta equal to zero, x equal to alpha. That is lower limit.

So theta equal to infinity, what is that x value? Also infinity, also infinity, yeah. Now this is an exponential integral for x. So what is the solution for this? This entire thing is, this definition of exponential, so we have e I of alpha.

So that is what is the conversion

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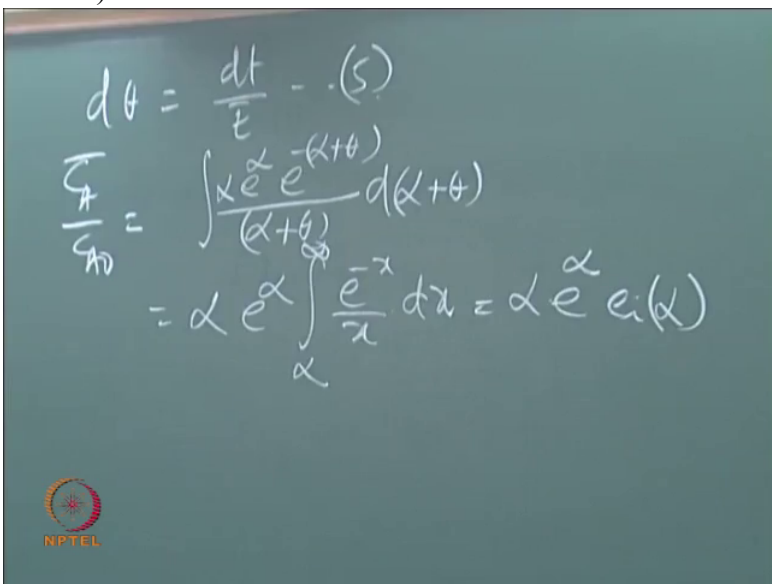

in a segregated fluid second order M F R, right? So if I now tell what is the value of alpha,

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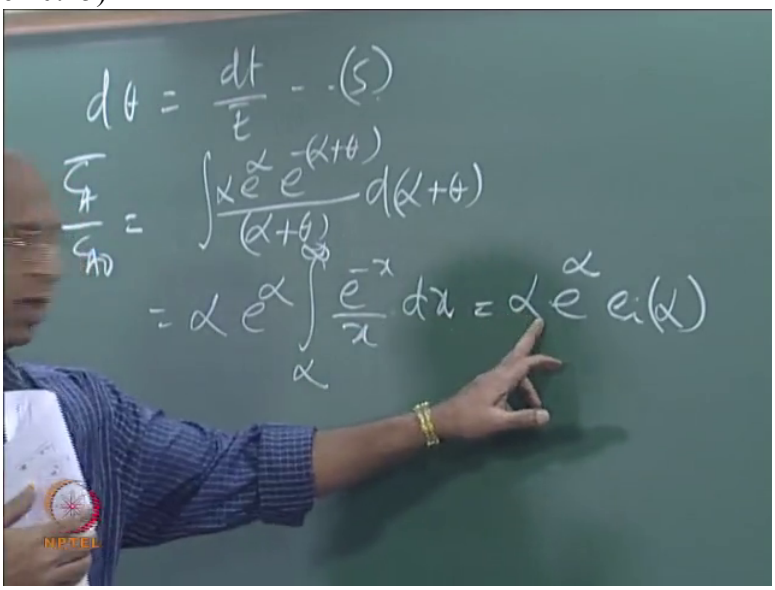

alpha is nothing but 1 by Damkohler number, right, if I say that Damkohler number equal to 1, 1 by alpha also equal to 1, Damkohler number, yeah so then you will have 1 e power 1 and e i 1. e i 1 value I have to get from, right, Ok.

So if you see Levenspiel, I think I will write also that one for the sake of completeness, yeah so e i x is given as yeah, of course integral is same thing, x infinity e power minus t by t d t because these are limits so any variable I can put there, because this is definite integral no, so that is why.

Then we have the values minus zero point 5 7 7 2 1 minus l n x plus x minus x square by 2 into 2 factorial plus, I think I have given you this one earlier also. But I am sure you will not remember that, minus etc.

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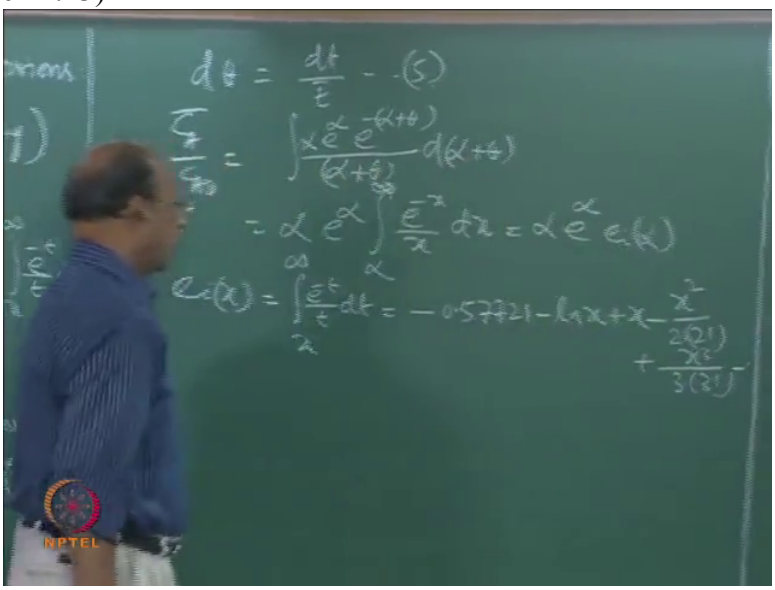

So now if x equal to 1, you can substitute x there and then calculate what is. Otherwise tables are given, directly you can go to the tables and then get it, Ok, good. So this is what.

Now if I say that I have alpha equal to 2, that means Damkohler number equal to point 5, Damkohler number equal to point 5, I have the values here. What is the conversion, C A by C A naught? I will also give you that values.

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Good.

If I have alpha equal to 2, that means alpha equal to 1 by k C A naught t bar, Ok, that is equal to 2

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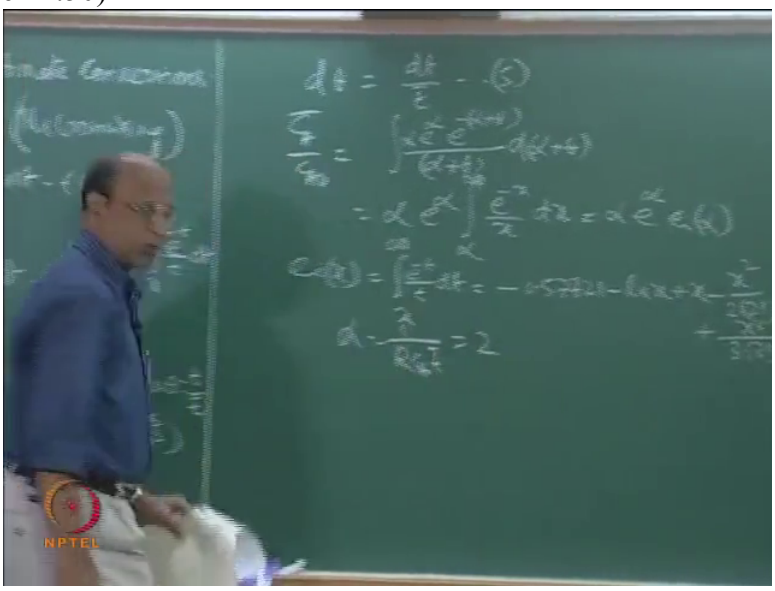

that means Damkohler number equal to half, right? If I have that value, how much is that? I think I can also give you the value of e of i 2 is point naught 4 8 9, point naught 4 8 9. The other values

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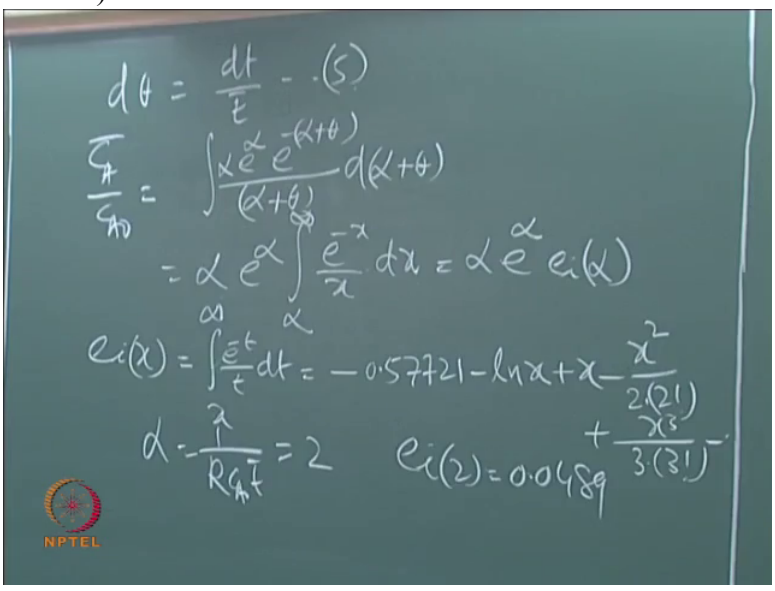

you can check.

By the by what is that you have to calculate? Yeah C A bar by C A naught in equation 6 that is what what you have to calculate, yeah. Point 7, excellent. So C bar A by C A naught equal to point 7 2 2 6.

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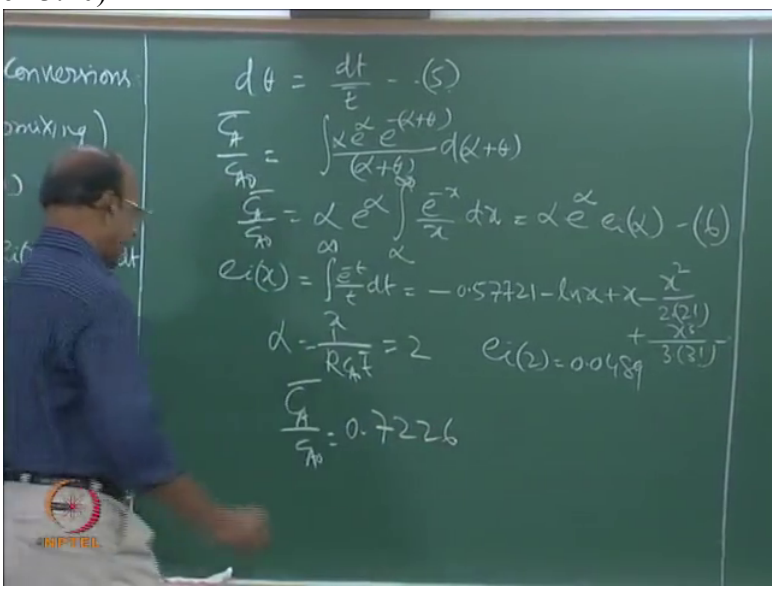

And X A equal to, yeah, point 2 7 7 4.

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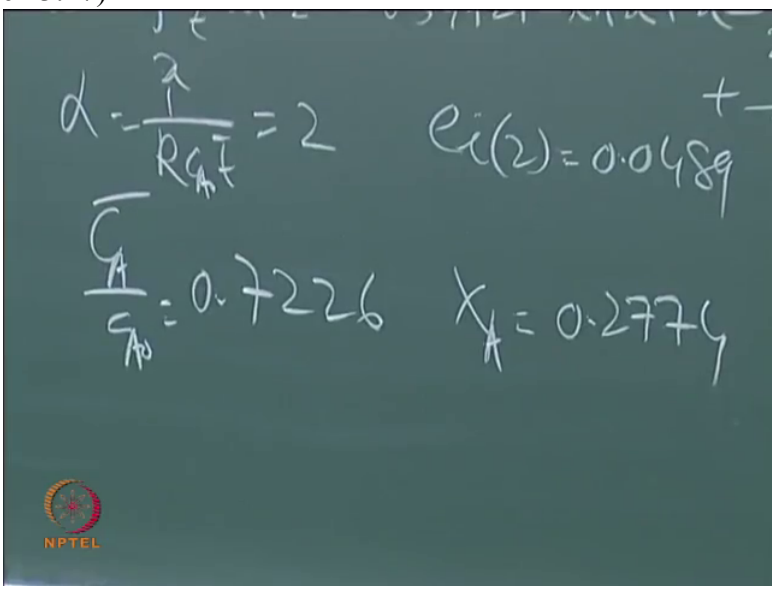

So we are now talking about macro fluid that is there in ideal mixed flow reactor. So now we have to compare this with micro fluid. What is the equation for micro fluid?

(Professor – student conversation starts)

Student: 0:14:01.0

Professor: What is the equation for micro fluid? Micro fluid is the fluid which you have already done in your B Tech.

Student: 1 by 1 plus theta C A naught, C A by C A naught

Professor: M F, mixed flow, we are only talking of mixed flow reactors.

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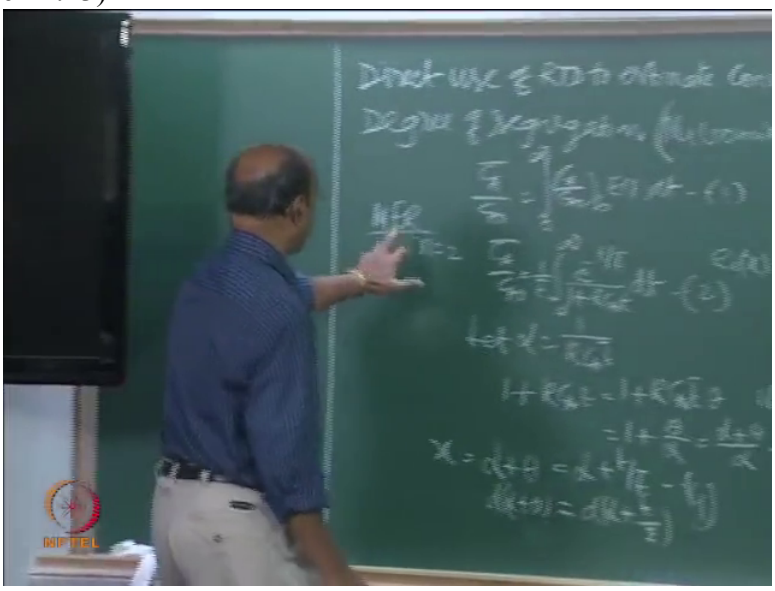

Student: 0:14:18.8

Professor: You cannot say easily because it is a second order reaction, it is quadratic function, right? So for macro, for micro fluid Ok,

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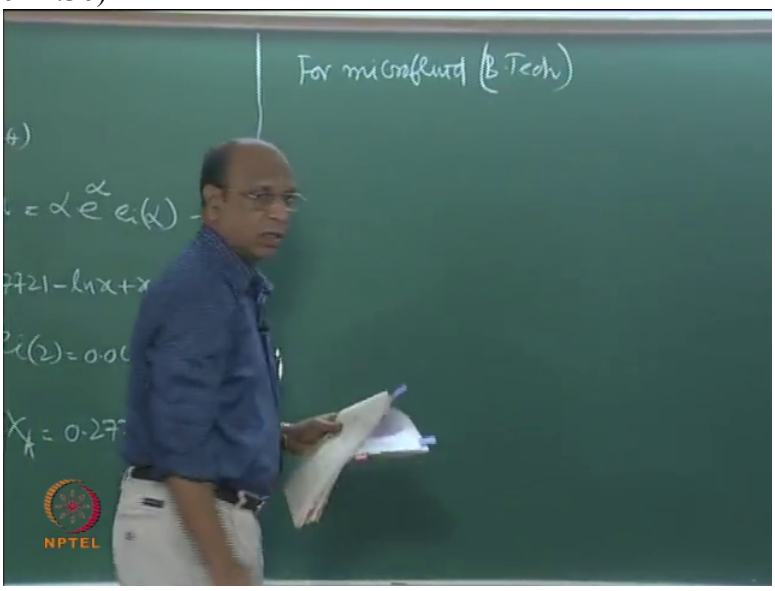

otherwise you will never forget, you will never remember, you know (laugh). So that means you know B Tech, you have already studied that in B Tech, right, yeah. Micro fluid B Tech. It has got degree also now.

(Professor – student conversation ends)

So n equal to 2, so the equation is a quadratic equation, C A by C A naught equal to minus 1 plus square root of 1 plus 4 k k C A naught t bar divided by 2 k C A naught t bar. So can you tell me this value? What is k C A naught t bar?

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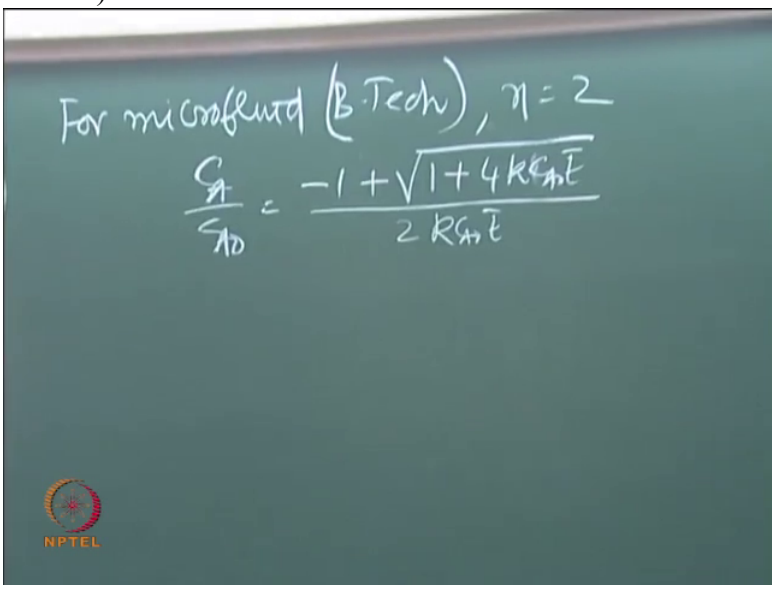

(Professor – student conversation starts)

Student: Point 5

Professor: Point 5, yes. So k C A naught t bar equal to point 5 which is also equal to 1 by alpha.

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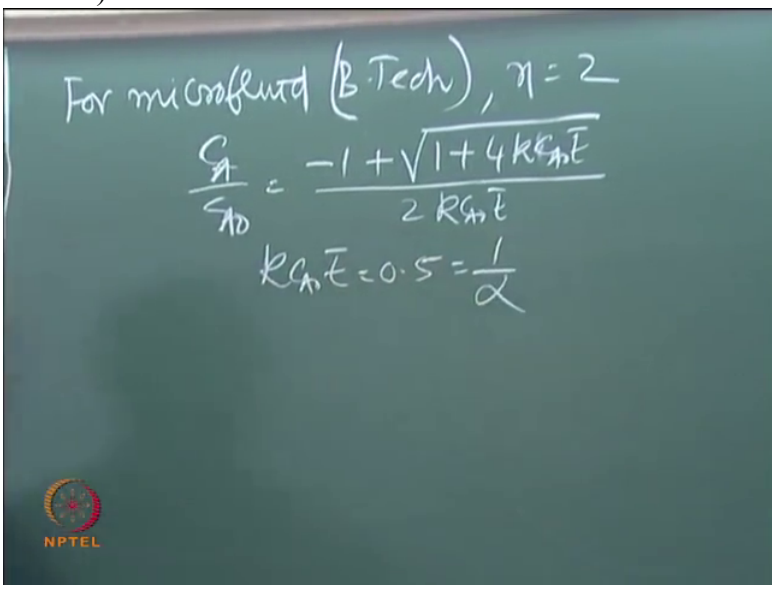

Ok quickly

Student: Pont 7 3 2

Student: Point 7 3

Professor: Yeah. C A by C A naught is, point 7 3

Student: 2

Professor: 7 3 2 1 and correspondingly the conversion point 2 6 7 9.

Student: Point 2 6 7 9

Professor: What is the conclusion? This is X A micro, correct no? So this is X A macro, macro fluid, that is what is the meaning of that... So what should be the conclusion? Which should be more? Micro is more?

Student: Macro is more,

Professor: Why?

Student: Mixing is less.

Professor: Mixing is less

Student: In second order reaction….

Professor: Mixing is less.

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Yeah Rajshree you were trying to tell something?

Student: The packets will be segregated ….

Professor: Yeah, because for second order, or n greater than 1,

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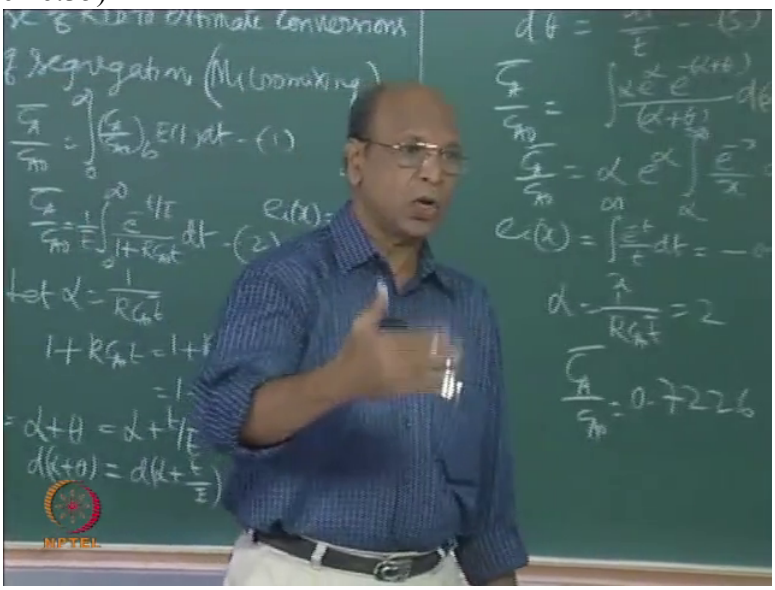

you have to maintain the concentrations as high as possible. So here in the pockets, the concentration is maintained as high as possible. But still it has residence time distribution.

(Professor – student conversation ends)

That means some packets coming early, some packets coming late. But if you are able to put all those packets again in mixed, in plug flow you will get still more conversion, because all of them would have converted into same conversion. Whereas now depending on its residence time distribution, zero to infinity exponential decay now you are getting this much conversion.

If you do now for half order reaction which we are not doing, so again you will get the reverse one. That means X A micro here for second order for n equal to 2, X A macro is greater than X A micro, right. So I think you know at least these things we will again reiterate and also reconfirm what we have discussed in earlier B Tech and of course beginning of this course, right.

I do not know in B Tech, any one told you like this. You know all that concepts like why we should have for second order more conversions, Ok, yeah when you have second orders we have to maintain the concentrations

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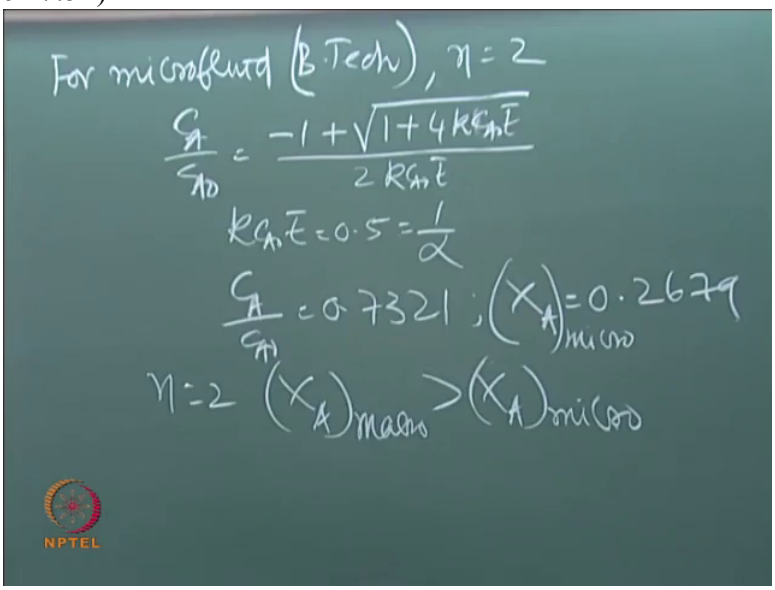

high and all that, right? But I think most of our system is only examination oriented. So but here at least I think you can appreciate now why, what has really happened at that time, now at least we try to understand that, Ok, good. So this is the one.

Now what is the conclusion for degree of segregation or micro mixing? Micro mixing is

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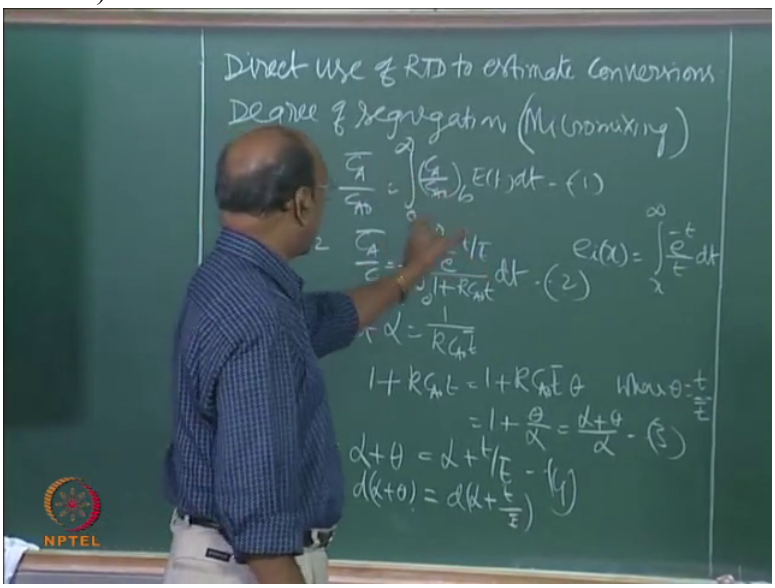

one of the components of overall mixing when you are talking about direct use of R T D to estimate conversions. Ok. What was the real problem? The real problem was that other than first order reactions, we have to use either late mixing or early mixing.

Late and early are simple humanities words, correct no, humanity, English Department words. But how late if someone asks, technically you should be able to tell. Now to define that how late we have now defined a fluid called macro fluid which will never mix that means I think any number of years it may stay inside the reactor but it will not mix with other molecules. That is what is the latest.

So our definition is as long as it is there inside the reactor, if it is not at all reacting with any other molecules or communicating with any other molecules, that is the latest mixing, right that is the one. How early is also is the one, is the question.

Because in our, this is a wonderful model, Netherlands, I think it is,

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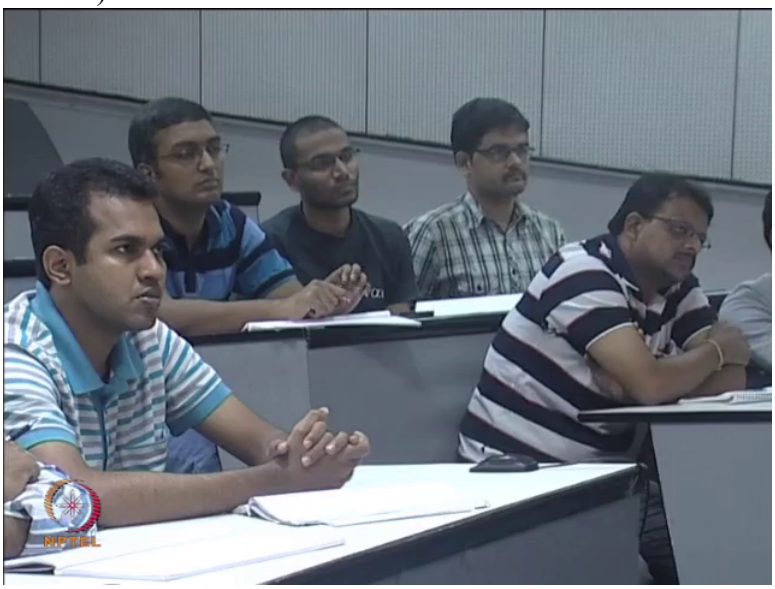

not able to recollect, it is Kramer you know who told that first. Right? Kramer, K r a m e r, Kramer. Not 0:19:20.1 I think, only Kramer, so this example. This is a wonderful example.

And yeah so here we say

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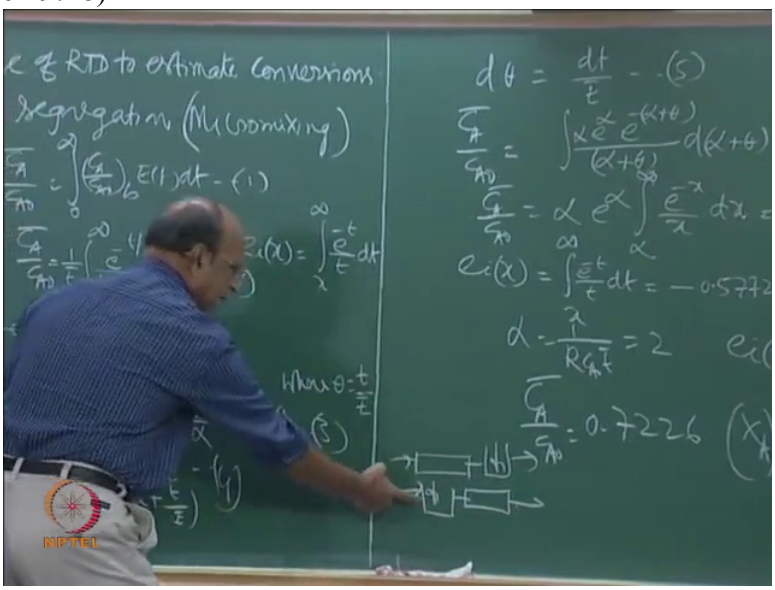

here early mixing and here we have late mixing.

And second question early is also answered by saying that we have

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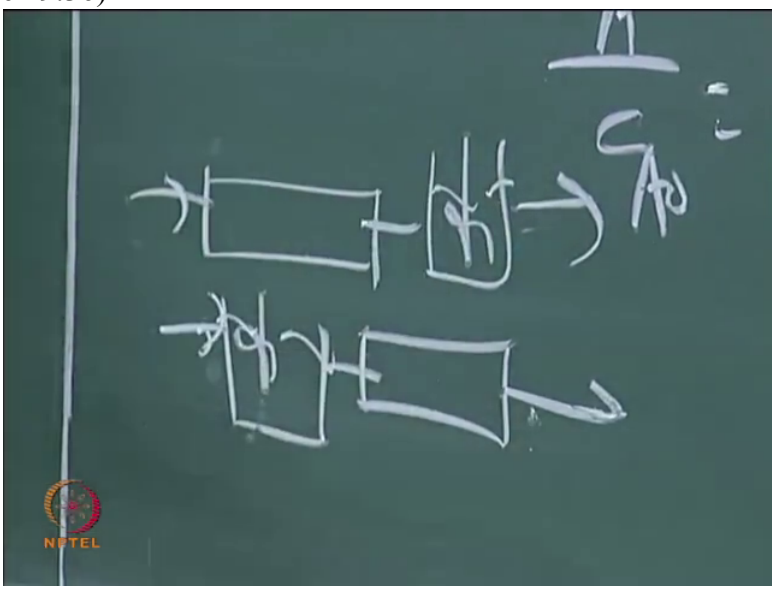

a micro fluid which can mix any, the moment, the instant it enters the reactor provided the reactor is allowing mixing. That is why that macro mixing is defined by reactors. Or reactors define, sorry; macro mixing is defined, Ok, reactors R T D is defined by macro mixing. Reactors, how late, how early.

Because here no, these two reactors only

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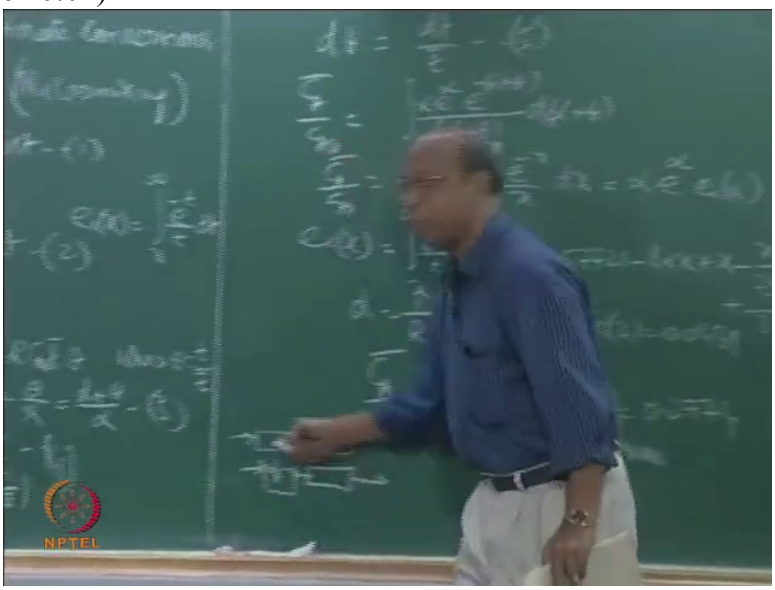

tell me how late or how early. Because this tells me that the reaction is late, Ok mixing, not reactor, mixing is late. And this one? Early, right. So that is why the macro mixing which is connected with R T D, that will clearly define saying that Ok, if I have a particular reactor, it may allow mixing, it may not allow mixing.

Because we have two reactors,

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which allows perfect mixing, the other allows zero mixing, no mixing. It will not allow any mixing at all. So that is why to suit them, we define this micro fluid and macro fluid, right. I think the connection must be clear now, right?

So only to answer this question early, late

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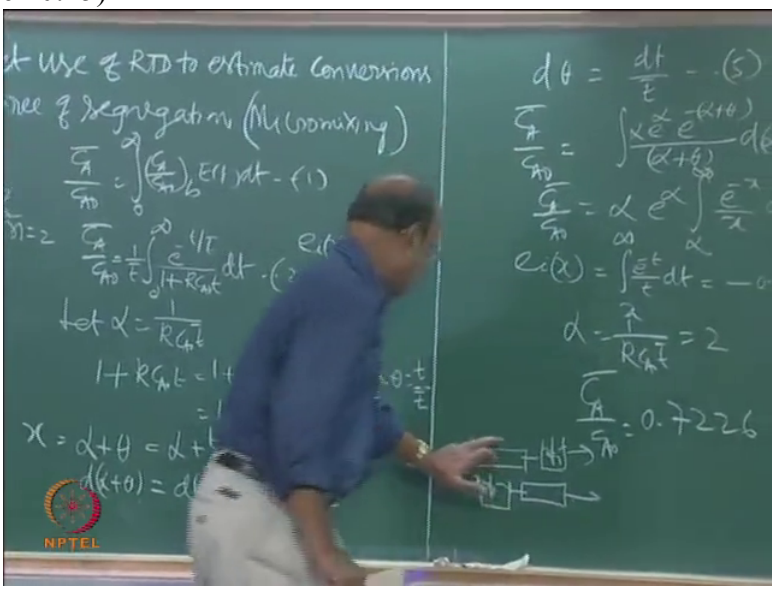

and early we have defined two extremes. One is a fluid which can immediately, instantaneously mix provided it is allowed to mix. Because that mixing is not taking place the moment I put the same micro fluid in plug flow reactor. Because by definition plug flow does not allow any mixing.

Mixing means overlapping of ages, that is also another way of defining mixing, Ok. Overlapping of ages. So that means if, first year M Tech people and second year M Tech people, if you do not meet them at all, so that is one packet and second year M Tech is another packet. Ok, this is segregated fluid.

But if you, both are allowed to mix, so that means your age inside the I I T, you just joined now, so that may be 6 months, and your seniors will be one and half months, one and half years, one and half years and now their age is different, your age is different but still you are able to mix.

So that means overlapping of ages is also indirect way of saying that you have mixing. What is happening in an ideal mixed flow reactor? The moment you have, anyway, under steady state conditions, something is entering, something is coming. And inside you have zero to infinity residence time distribution.

The moment you send any fresh batch, so now the molecules can mix with any other molecule irrespective of its age, correct no? So one molecule may go, just entered, may go and attach with a molecule which is, now 15 minutes back it entered, one, here, one minute or one second I said, Yeah one second and 15 minutes back some another molecule entered, both may mix together and then just come out, Ok.

So that is what is life expectancy. After they come together, their life expectancy is, yeah same for them because both of them are leaving together. Right. That we cannot have good example in M Tech, right? Yeah. Because even though you...this is plug flow. That is why you do not have that example, right.

Because you have to spend 24 months and your seniors also have to spend 24 months to get the degree. Ok, so that is what. That is what is another definition of mixing. I think that also I will just quickly discuss, very quickly...10 o'clock...yeah so that, this is fine, no? This is very clear.

And lessons from here is do not worry when you have batch reactor or plug flow, whether you have macro fluid or micro fluid you do not have to worry. So micro mixing, macro mixing will not come into picture and all things, like degree of segregation will not come into picture, maximum mixedness will not come into picture. All these things will disappear.

Problem is only with M F R, right. So M F R also, micro fluid you already have the equation, B Tech, right or M Tech beginning, right? Ok, and only segregated fluid we have the problem just to imagine that how do you, what is happening for the segregated fluid inside the mixed flow reactor. That is what what we have defined here.

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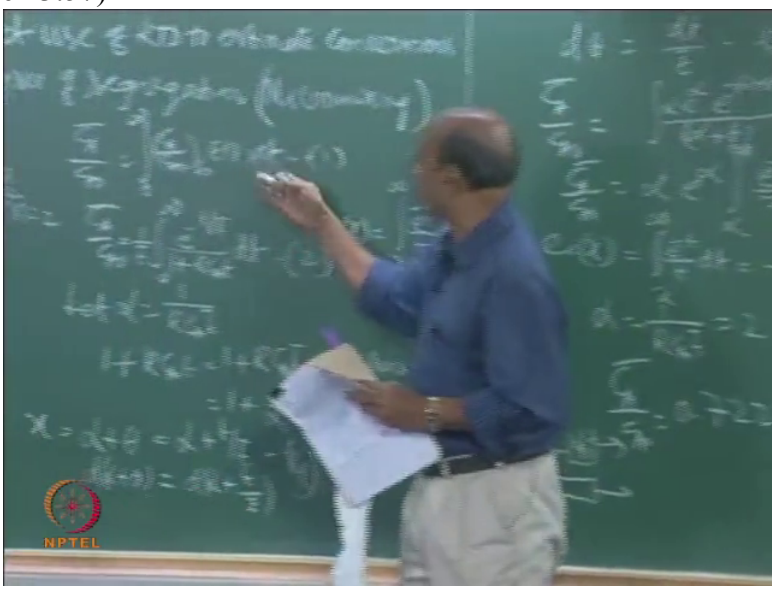

So depending on how many fractions are, how many packets are spending within this time, the time that is may be 1 minute, 2 minutes, 3 minutes like that, you have the conversion in that fraction. Like that all fractions are added together. This is nothing but sigma, right, yeah? So then you will get the average conversion or average concentration that is left inside the packet, Ok. Good.

The other one what I thought I will just quickly tell is about...Ok, that I will tell

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later. then the next one we will see, take now. Ok, that alpha, gamma I will tell, no, you know age and

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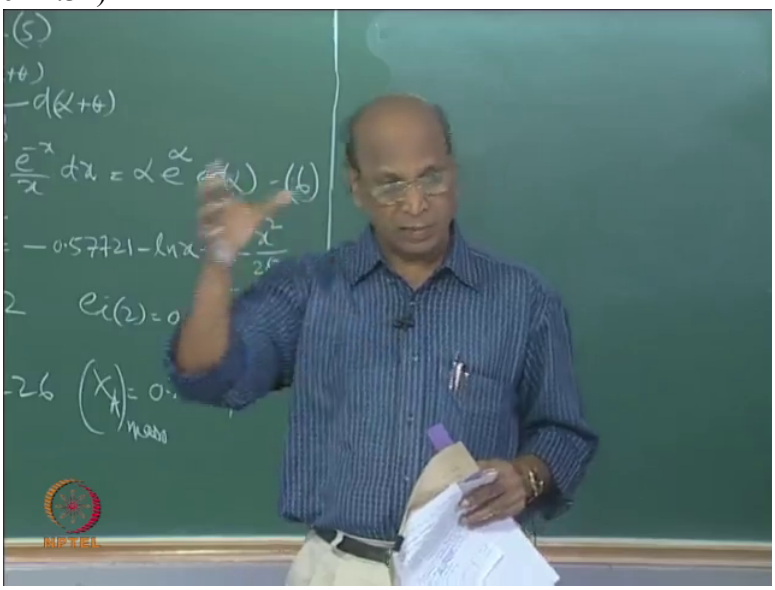

life expectancy I can tell a little bit later also. So Ok. What is the next one?

We had 2 parameters, micro mixing and macro mixing. So micro mixing we have discussed now. We have taken 3 reactors, Ok and then we have discussed first 2 reactors, batch and plug flow, no problem at all. Only M F R segregated fluid is the problem.

Now we have proved that even here, macro fluid gives more conversion than micro fluid because micro fluid allows mixing. Whereas macro fluid does not allow mixing. So that is why. In fact

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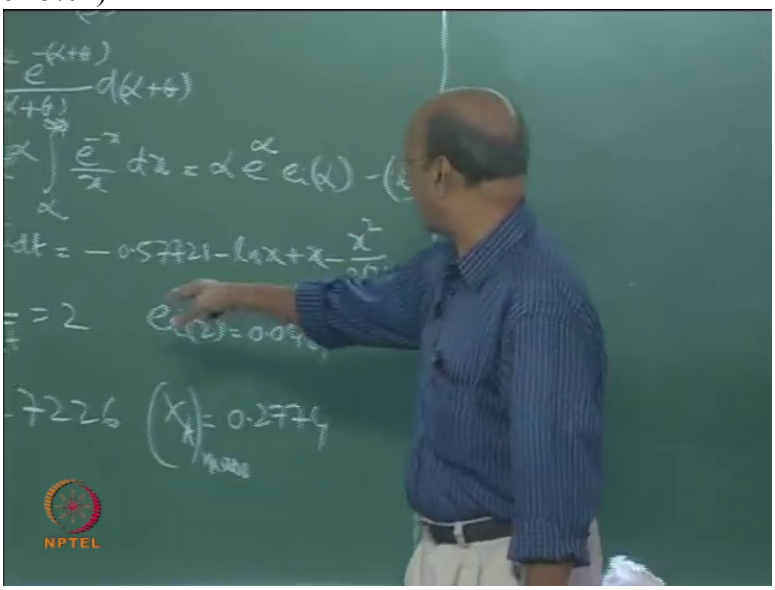

the Damkohler number what we have taken is very small, point 5. Correct no? Yeah.

If you take larger Damkohler numbers then the conversion difference will be slightly much better. Here we have only, how much,

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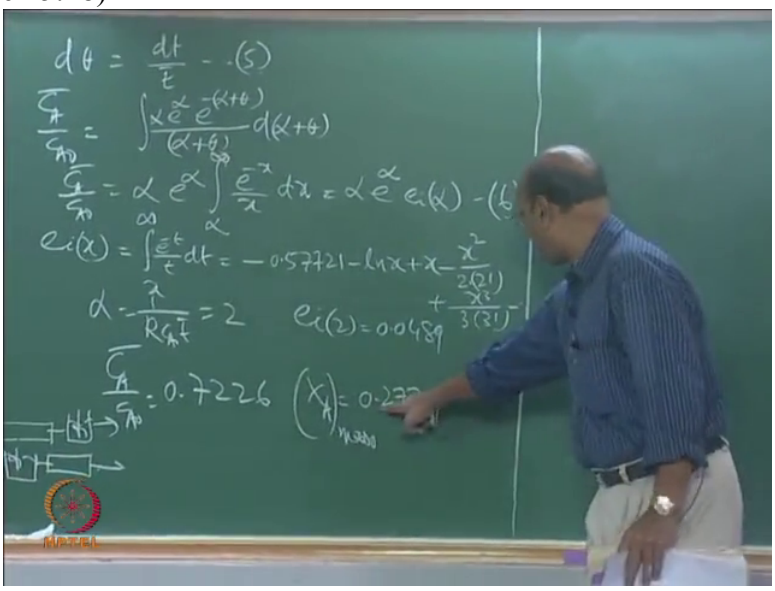

this is point, this is 27 point 7 percent. The other one is 26 point 7?

(Professor – student conversation starts)

Student: 26 point 6 9

Professor: Yeah, that is all. That means only you know, point naught 1 percent, right, no point naught 1 difference, 1 percent difference. But if you go to larger and larger Damkohler numbers you will see clear difference, right? Good. Nice.

(Professor – student conversation ends)

So what is the next one that is left now? Maximum mixedness, Ok maximum mixedness or what is the other word for this? In the bracket? Macro mixing. Macro mixing is the word that is given there, good? Yeah, let them settle and let them, let me also draw this.

This is the degree of segregation. This is segregated, maximum mixedness. Yeah, the other one is this.

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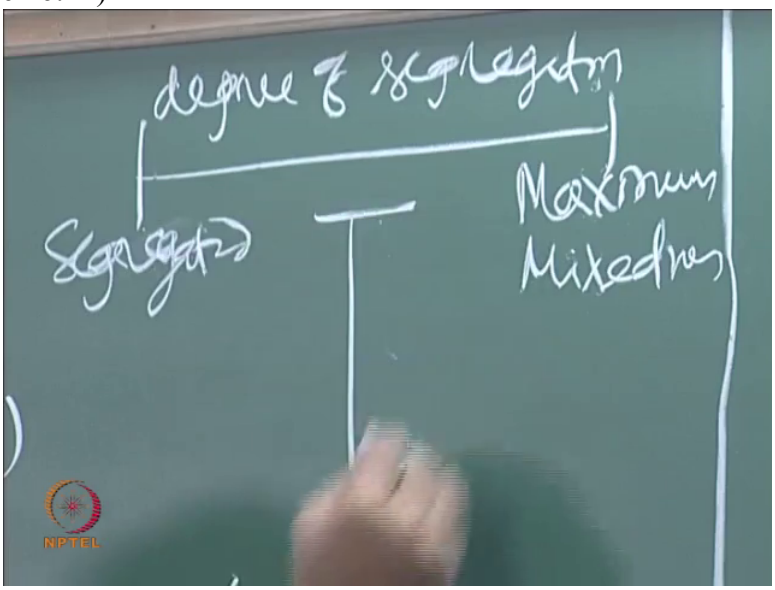

This one also, of course micro mixing, micro mixing and then here I have P F below no, P F top? P F below, M F top

So this is R T D equal to, yeah I have not written earlier, zero. And this is R T D equal to zero to infinity, Ok that is the two extremes.

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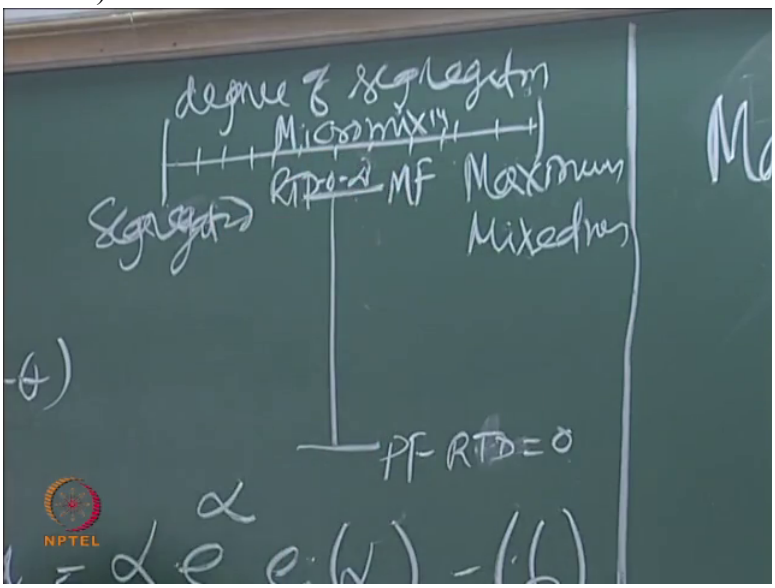

And macro mixing is increasing in this direction. Macro mixing, Ok

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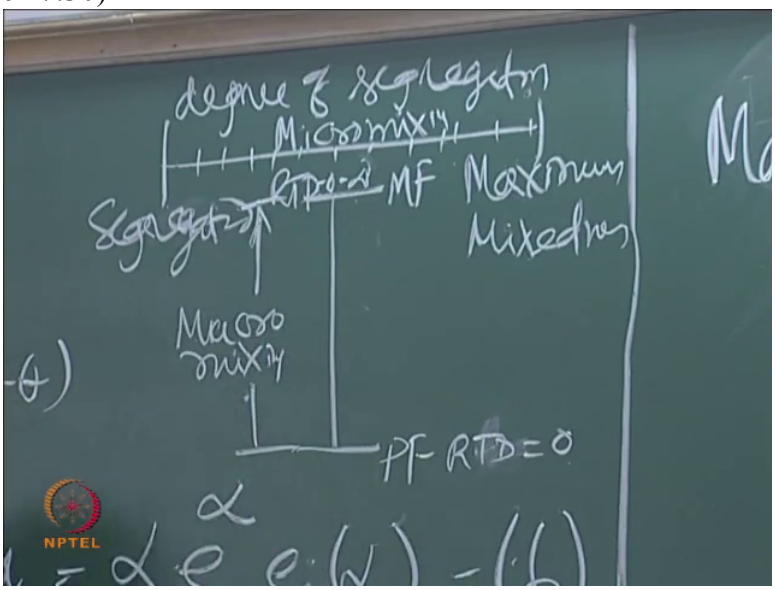

Ok and I also have all intermediate R T Ds. So all these things are intermediate R T Ds. These are the extremes, Ok good.

So these are

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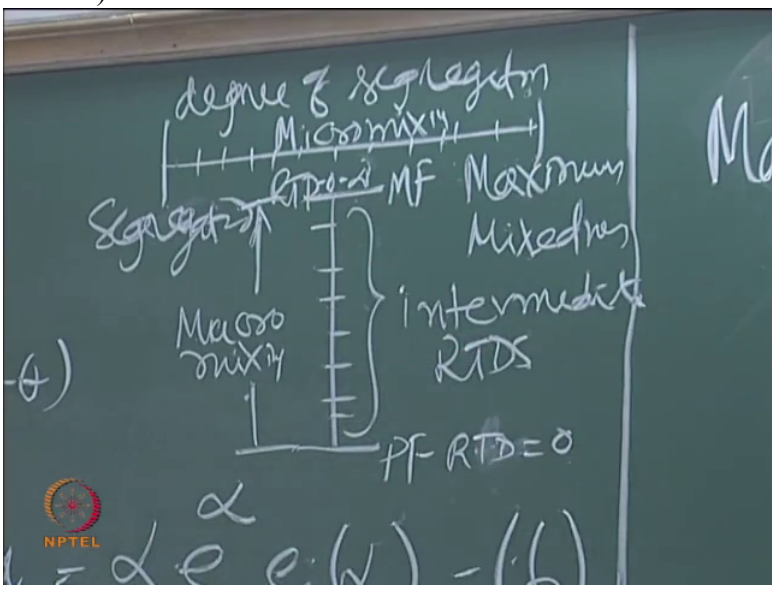

the things only what we are talking. Now macro mixing, macro mixing should define R T D, right? Macro mixing should define R T D, that means on this scale, I have a zero R T D and on this scale, here, on this end,

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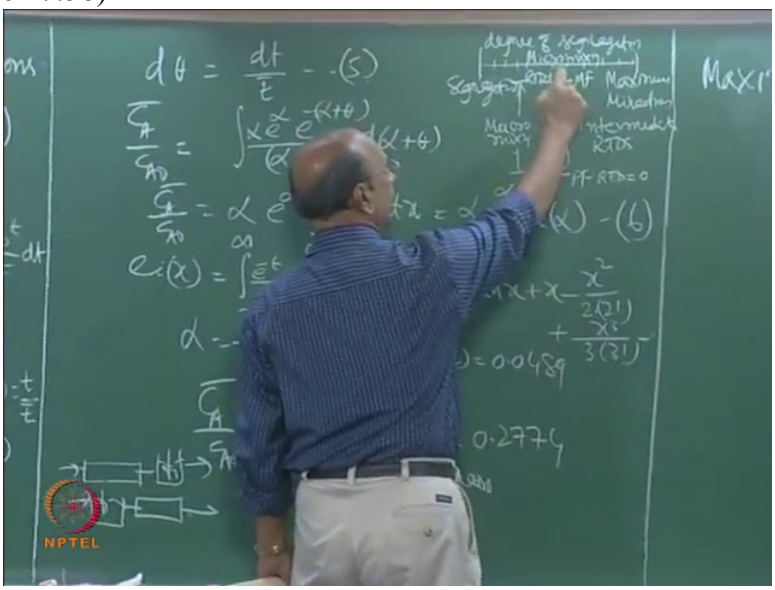

I have zero to infinite R T D. Macro mixing is a name that is given to describe R T Ds, Ok good.

So now I will give you the extremes first. Like because now we are talking about R T D only. We are not talking about reactors. I will say that I have a system with direct delta function R T D. I have a system with direct delta function R T D. So what is the meaning of that?

Idealized, Idealized pulse or in the bracket delta function I can write, delta function R T D. Ok this is case 1. So one extreme we are talking. What are the, how many kind of reactors can give me this kind of idealized pulse

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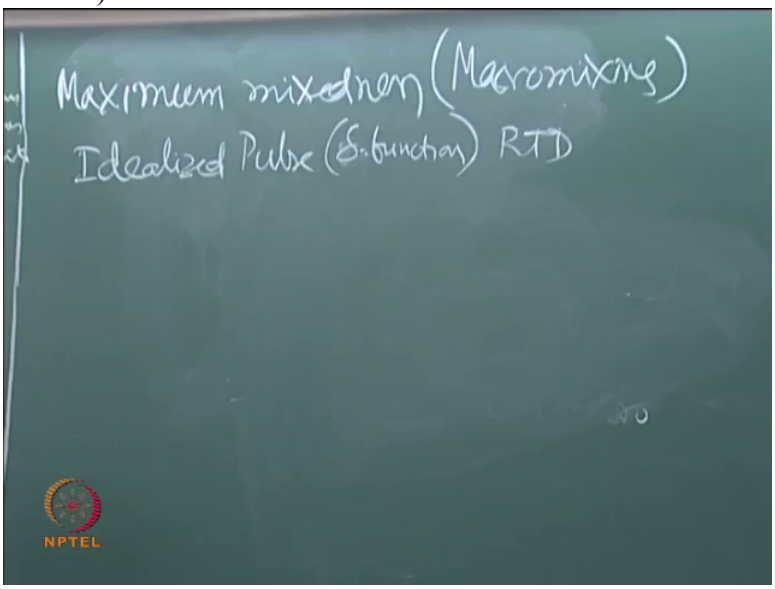

R T D? We are asking the reverse question. If I have plug flow, definitely I will get idealized pulse, Ok right if I have plug flow.

I am not, I am not telling anything about the reactor now. I am only telling about, I have a pulse. What are the systems you can bring under this pulse that can describe R T D? What are the other reactors or whatever possible reactors, Ok that will give me idealized pulse? What is the meaning of idealized pulse?

(Professor – student conversation starts)
Student: High 0:29:38.1
Professor: What is the meaning of idealized pulse?
Student: Zero to...
Professor: Not mathematical meaning, physical meaning.
Student: At zero time
Student: As time increases...
Professor: Yeah. Zero time?
Student: Zero...
Professor: What do you mean by zero time? Idealized pulse this we are talking about outlet only. We are talking about E t
Student: V pulse.
Student: 0:29:59.0 Amount is the same.
Professor: That is the one.
Student: Yes
Professor: Each and every particle must spend exactly the same time.
(Professor – student conversation ends)

I think in this semester I could have told the same thing I think thousands of times, if someone would have counted, Ok. Yeah. So here also in a different way only we are trying to tell again. So if someone tells me that I have an idealized pulse R T D, the meaning is that, each and every particle is spending exactly same time.

So what is the reactor that makes this kind of zero residence time possible? Now we are asking reverse question. If I have plug flow, I will definitely get this because that is the definition of plug flow, right, Ok. Savita, left? No. Ok. good.

So if I have idealized plug flow then definitely I know that I will get direct delta function. Why? By definition, each and every particle should spend exactly same time. Now I am asking the reverse question. I do not know what system I have. But someone came and told me this is the pulse I got from my experiment that is exit, exit pulse only what we are talking. That means E t only.

So or otherwise I can also write this is E t equal to delta E t minus t bar.

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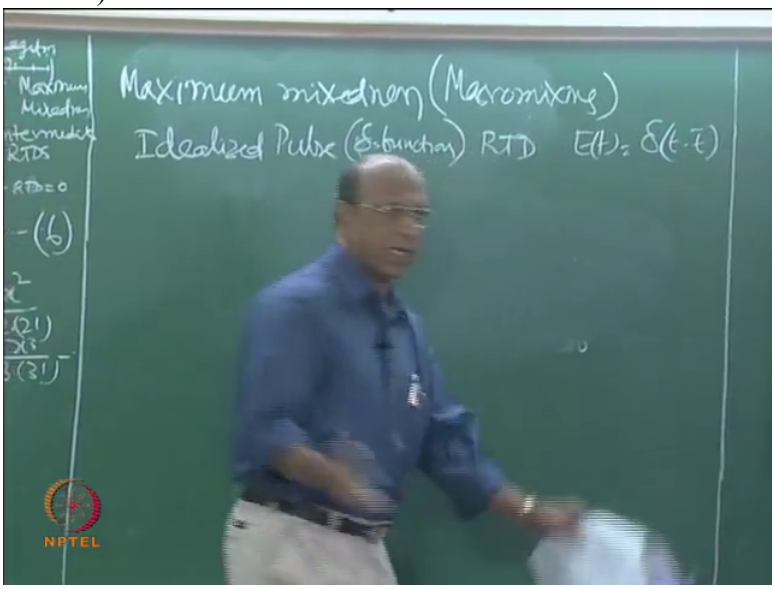

Because I cannot write t bar P. It can be anything. Ok. So at t bar all the things are coming out. So before that or beyond that I think that delta equal to zero. Good, yeah so what is that possible, which system will give me direct delta function as E t?

Yeah only system that is possible here is, only plug flow. No other system can give. Because direct delta function, thickness equal to zero what is the meaning? That means width equal to zero, distribution equal to zero. So when can you get this? Unless each and every particle spends exactly same time you will never get that.

So when each and every particle spending exactly same time, what must be the reactor? Plug flow. And if you consider the other one, you know, you cannot say it is, it is not a flow system, in batch also residence time distributions are zero, correct no? In batch also.

Now when I have this kind of idealized pulse, E t equal to delta t minus t bar, and do I have to worry about micro fluid or macro fluid? You do not have to worry. So again, even in macro mixing scale, in this scale this end is very good end for me, trouble less end.

Because even in macro mixing scale if I have

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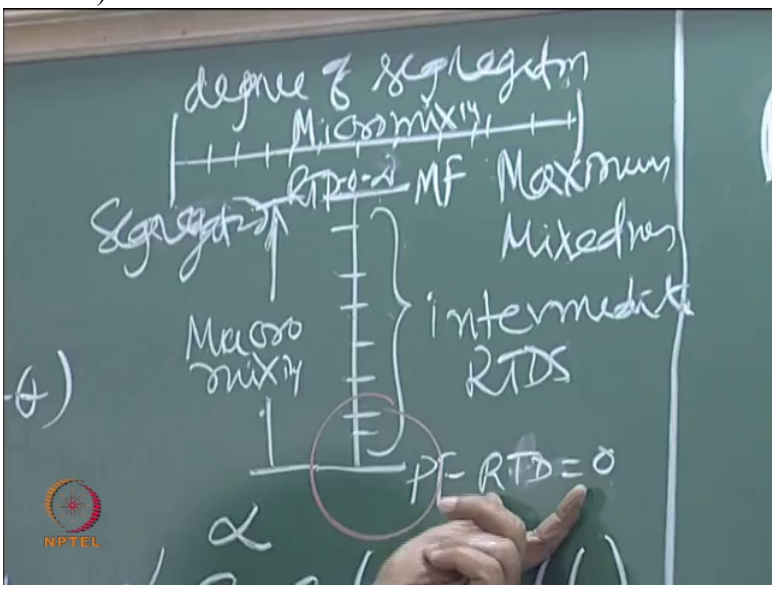

R T D equal to zero that is E T, delta t minus t bar, again I do not have to worry whether I have micro fluid or macro fluid. Why we have to worry about micro fluid or macro fluid? Micro fluid allows mixing whereas macro fluid will not allow mixing, right?

So because it is a plug flow reactor, whether I have micro fluid, macro fluid both should spend exactly same time. Conversion will be same in that. So when I take average, micro fluid or macro fluid or batch reactor should give me exactly same.

At least you know number of times when I am telling it should be permanently somewhere adsorbed in your brain till you die, even if you do not join, you know chemical engineering job. Because I think so many times you heard, so I think you cannot forget. Unless you take a

brush and then really rub it out. Ok. I do not think you can reach that with a brush. The moment you reach it, out again.

So that is the reason why so many things, you know again it is only repetition. I told you no, we are not learning anything new concepts. These are the same concepts but by number, different number of ways when you are learning, your learning will be perfect.

Otherwise only once if you tell, only that Ek, what is that called Ek Santa grahi, I think in Sanskrit they call them. Because only once they hear, and then they can remember. It is like computer. Computer is Ek Shabda grahi. Because one click enough, it stores. Correct no, it will never, unless you go and delete it is there permanently till computer dies. Unfortunately our brains are not like that. Ok. That is the reason why I have to repeat number of times, right, Ok, good.

So again when you have this delta, only P F, plug flow reactor will give idealized, idealized pulse. Ok. Hence macro and, macro fluid and micro fluid give same conversion, same conversion in plug flow, right. It is a continuous, there is no comma there. There is no full stop. There is comma.

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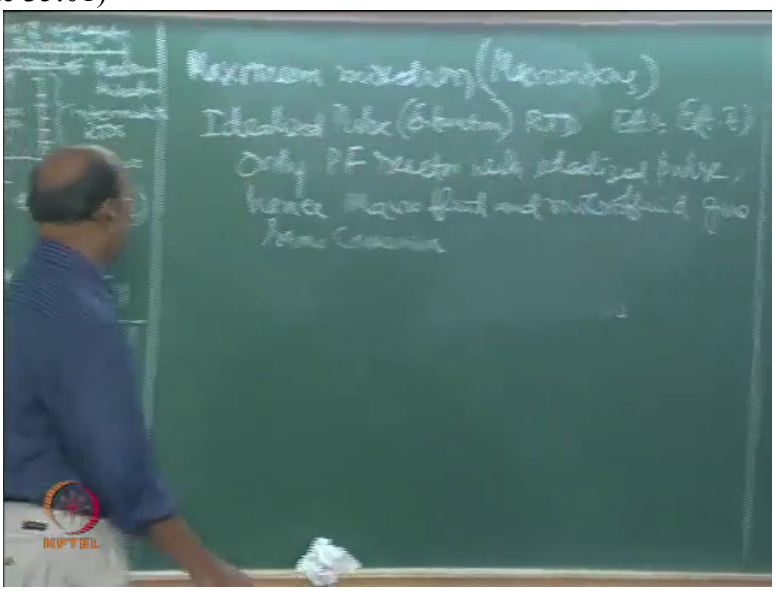

Hence macro fluid, micro fluid will give the same conversion, excellent, Ok good.

Now you can store this one in a separate file. Ok. In your brain. So next one.

Next question is let us take now exponential decay curve. That is another extreme. In between I think we do not have to do anything. Ok. So now, for, I am not saying we have M F R, I have simply exponential decay curve. Second one is exponential decay curve,

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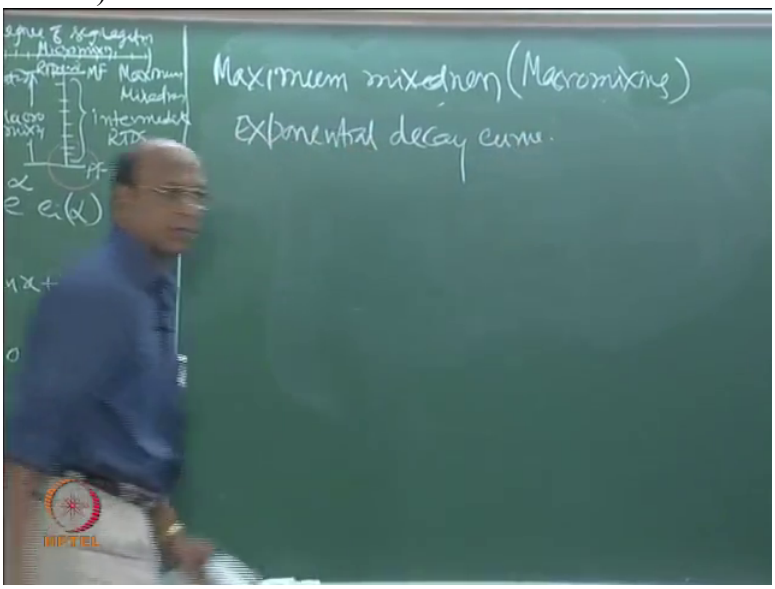

right?

That means I have here E t versus t, then exponential decay, Ok. So now what is the system which gives me this?

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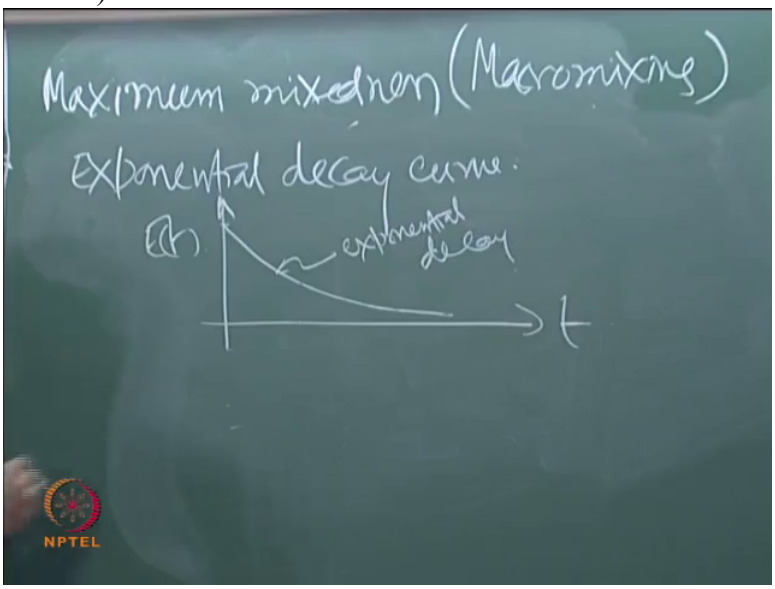

Plug flow. Yeah, so ideal mixed flow is one, this is one, Ok. Ideal M F R.

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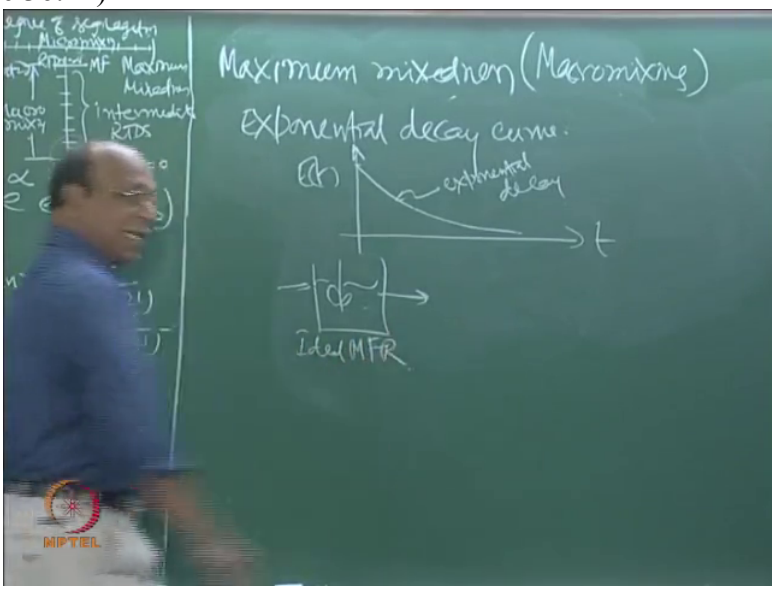

Any other system gives or only this is possible? Difficult to answer, I will tell you, there are many, many, many types of systems which will give the same exponential decay, right?

Let us see them. Let us see how many are there. Few of them we will take and you will appreciate this, Ok. Now let me take, to create this kind of exponential decay, I will take plug flow, small one, slightly bigger one, slightly bigger one, slightly bigger one, slightly bigger one to match all these. So that means I may have a system where, still down, like this, like this because theoretically this is possible.

Like this, any number I can draw. So now and again, so this is volumetric flow rate, this is volumetric flow rate. This also gives me same exponential decay, correct no? Because this particular

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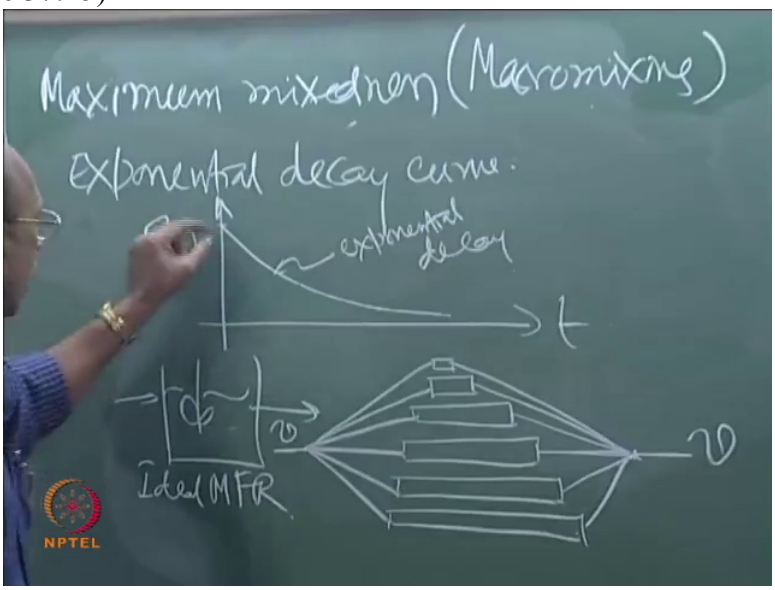

one which is coming very, very quickly may be between zero to 1 minute is coming here.

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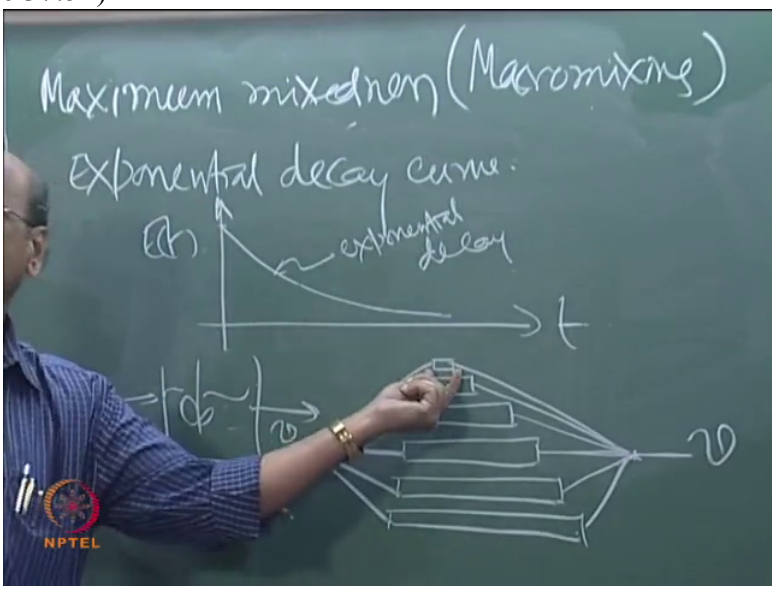

So next one, 1 to 2 minutes is coming here, right.

So like that the entire thing I can simulate using any number of parallel P F Rs. These are parallel P F Rs. Yes. See what is your idea? Idea is only to get that much fraction,

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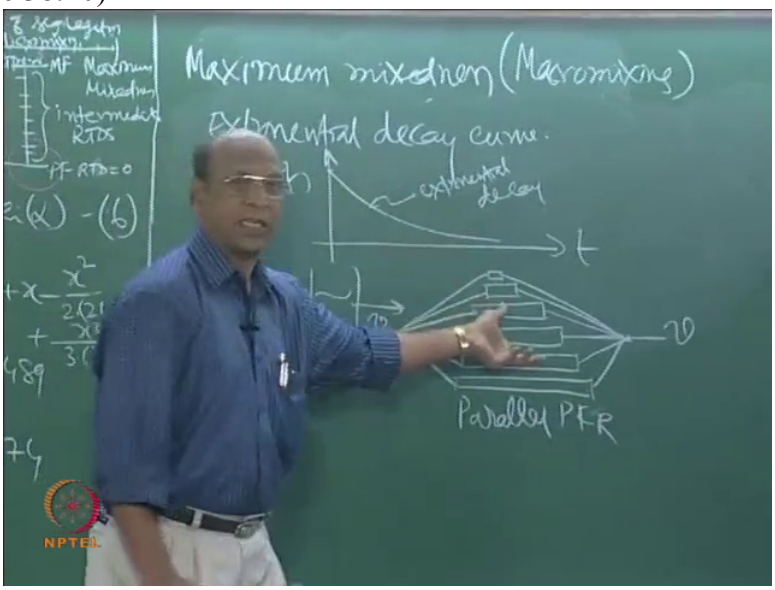

right? So between fraction spending time between t and t plus delta t.

So to get that fraction, you have to naturally change the flow rates, right. The idea is whether you are able to get that kind of E t versus t graph or not, right. This is one possibility. Now you see another, very beautiful possibility.

Another possibility is I have ideal plug flow. Ok this is ideal plug flow. So then what I do here is, this also gives me same exponential function,

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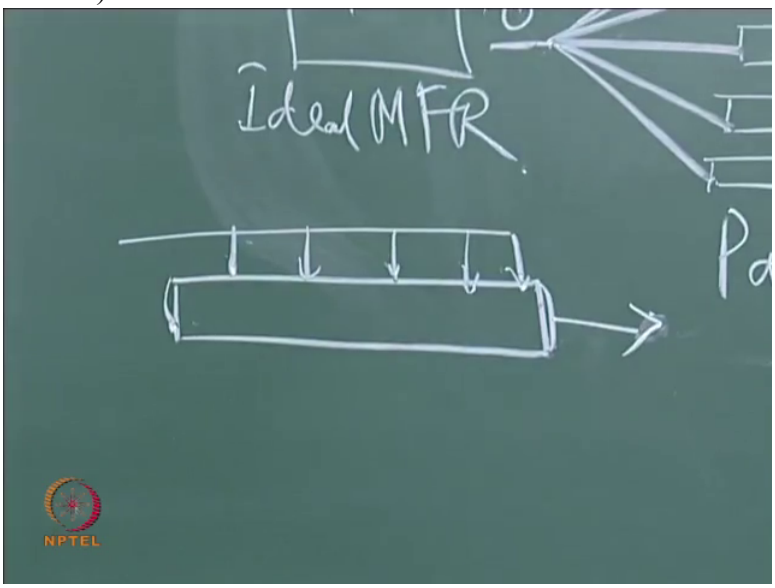

correct no? Because I have a parallel pipe and then I am introducing here which is just coming out, where is this

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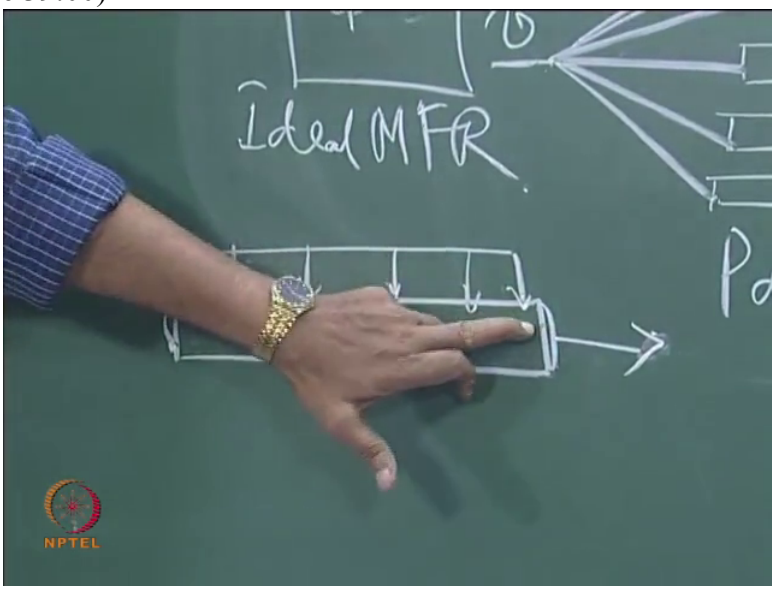

point, Swamy? Here.

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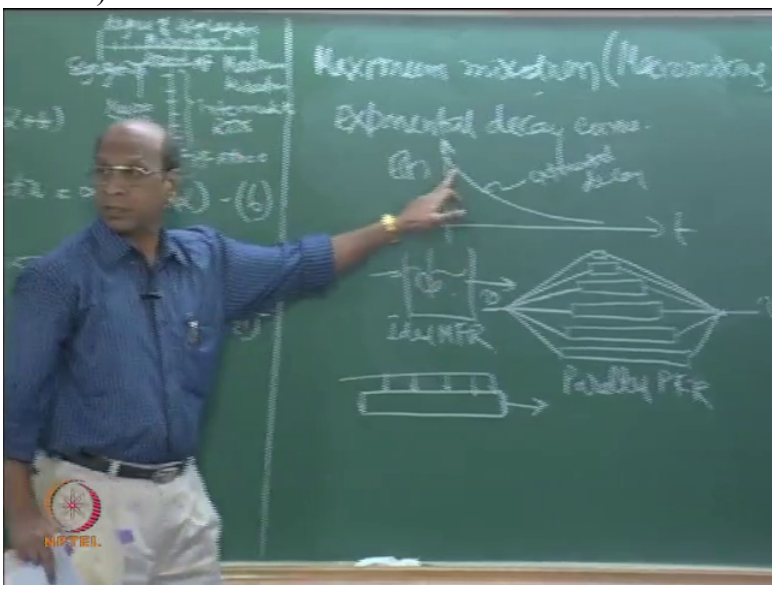

Because that is coming very quickly,

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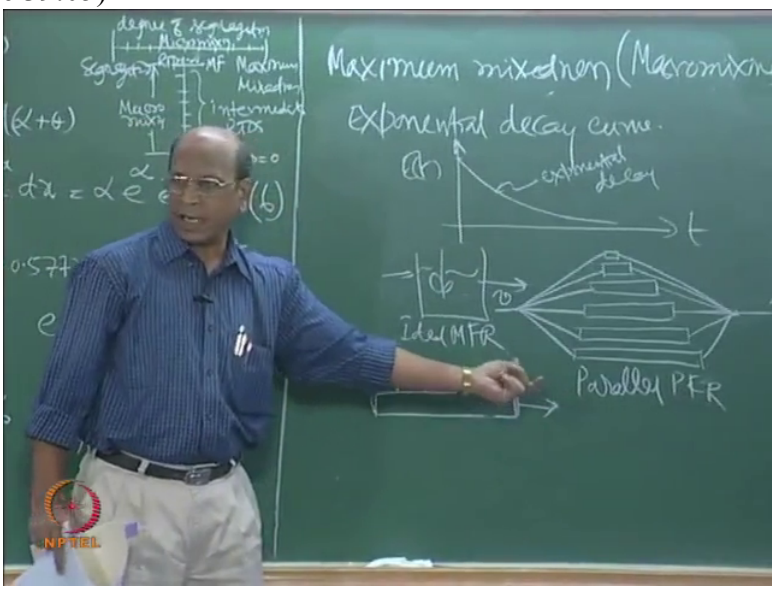

right? Yeah. And also that is coming very quickly at this point, the life expectancy of a molecule which is coming here,

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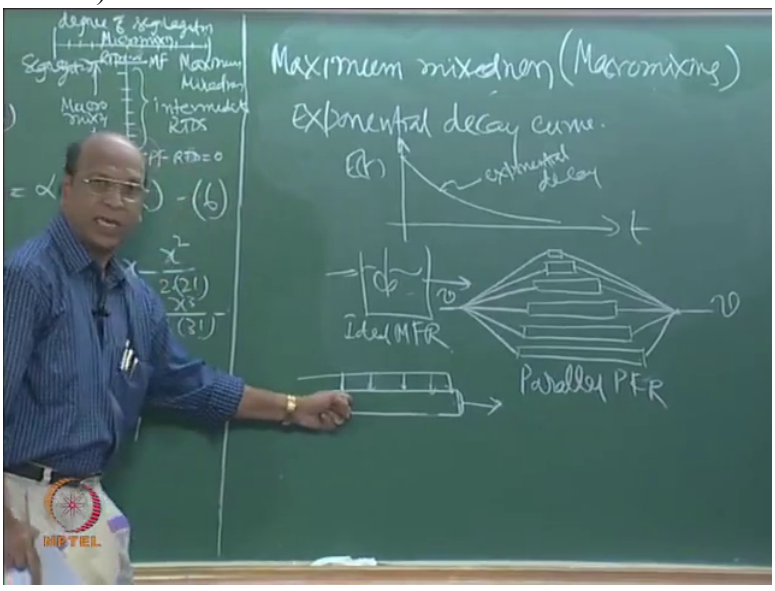

and also its age, two ages are different, right? This is just entering.

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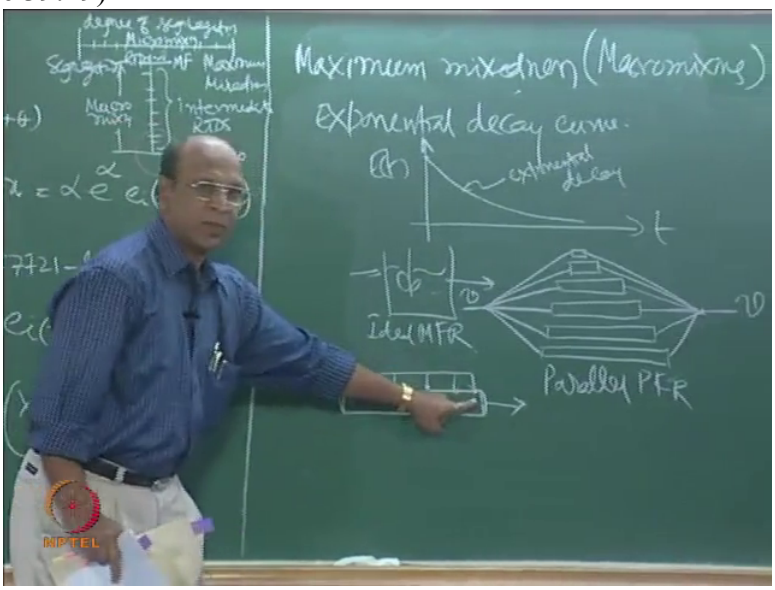

And it is continuous flow. So the other one probably which has entered here, would have come and then just joined. Both will just go out, right? So that is what is exactly what we call as mixing.

Mixing is whenever you have overlapping of ages. I told you no, example. If you are mixing with your seniors then you have mixing. And if you are not talking to them and then if you do not know also who they are,

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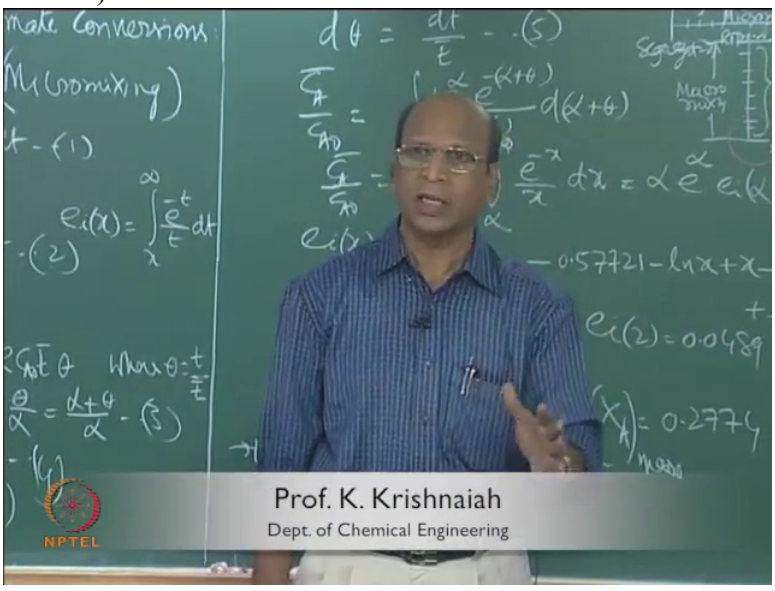

right, your M Tech class is a one packet, and your senior M Tech class is another packet. That is segregated fluid. Right.

So when you mix, then it is yeah mixed, it is I think, you cannot say it is maximum mixedness. Maximum mixedness is from zero to infinity, Ok residence time distributions and zero to infinity life expectancies when they over lap each other that is maximum mixedness, that is this corner.

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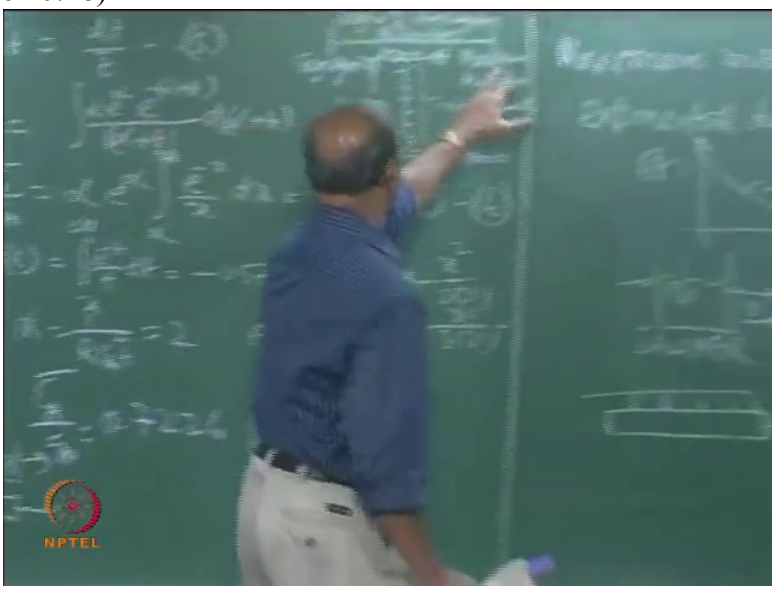

That will happen only in case of which reactor?

Only M F R for micro fluids. That is why it is called maximum mixedness. And micro fluid will give that kind of thing if I have that kind of overlap between life expectancy and the, what is that other one, age. And also that is why again, beautifully we say that inside contents of mixed flow reactor is exactly same as outside, outside.

That is why the distribution of residence time inside and residence time distribution outside, again exact, otherwise that condition is not fulfilled. Without knowing all this, in the beginning itself what we say in the B Tech, yeah, assume that temperature is same, concentration is same, conversion is same inside the reactor and outside the reactor. I also did not tell you at that time.

Because if I tell you all that at that time, by this time you could have totally confused, Ok, unless otherwise you know I teach you totally in different way. Tell the concepts first and then you can go, that is another way of telling.

So normally teaching is two styles. One is that you teach generalities and go to specifics. Like transport phenomena. You take Navier Stokes equation, right. That is the generality. So any system can be described under Navier Stokes.

Now depending on which system you are talking, throw out some terms. That will be specific applicable to some specific system. Otherwise you can now start with specific system, assume simplest one with so many assumptions, simplest system and then remove one by one assumptions later, slowly complicate, take another system with less assumptions. Another system still less assumptions. Another system, still less assumptions. Finally you will end up with whole Navier Stokes, Stokes equation.

So here also we can do the same thing, in reaction engineering also. First giving the theory of all this micro mixing, macro mixing and all that. Then apply to first order reaction, second order reaction, separately mixed flow, separately plug flow all that you can. Luckily we have only 2 systems, plug flow and mixed flow, Ok. Good. This is the one.

And not only this. There is another one you can see. Or if you have some more things also you can tell me. So this is also an ideal P F R, P F R is always ideal, P F R. Now you can see how nicely this can also be managed. I will now send the flow like this and withdraw here. This system

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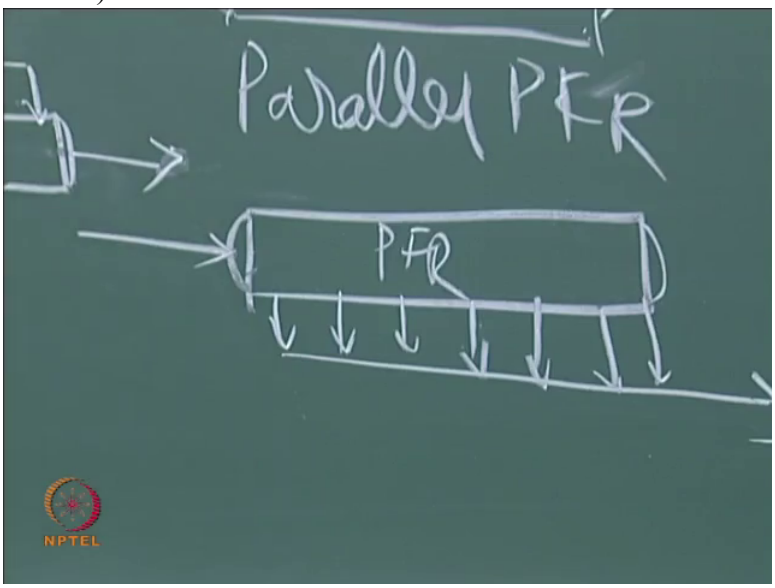

also gives me exponential decay. So what is that we have learnt there? Nothing? That may be the truth. Truth hurts. 0:33:21.2 Sushmita?

(Professor – student conversation starts)

Student: We cannot say anything.

Professor: Yes?

Student: Even the R T D we cannot say which system...

Professor: Yeah, given the exponential decay, if I block all this, you can never say what system you will get.

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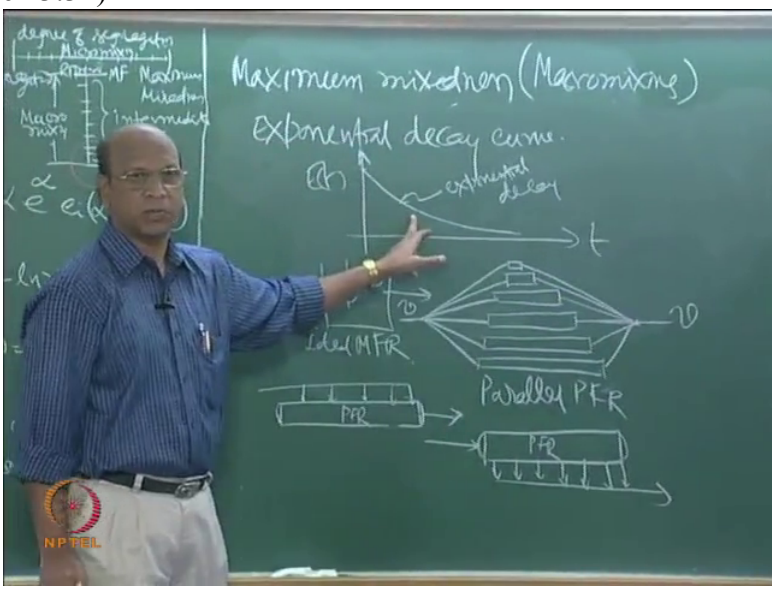

That is what exactly this also tells me.

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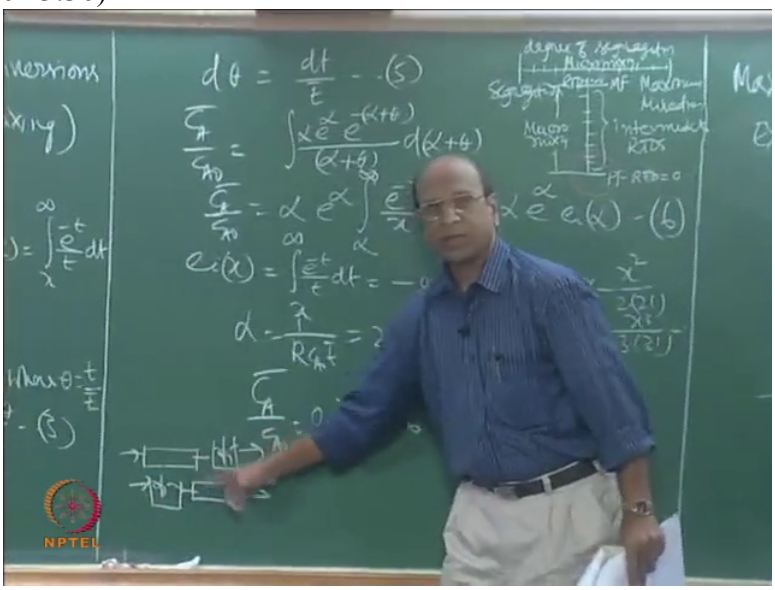

The residence time distribution curve for me is simply like this, correct no? E t versus t.

(Professor – student conversation ends)

But now if I give you this one

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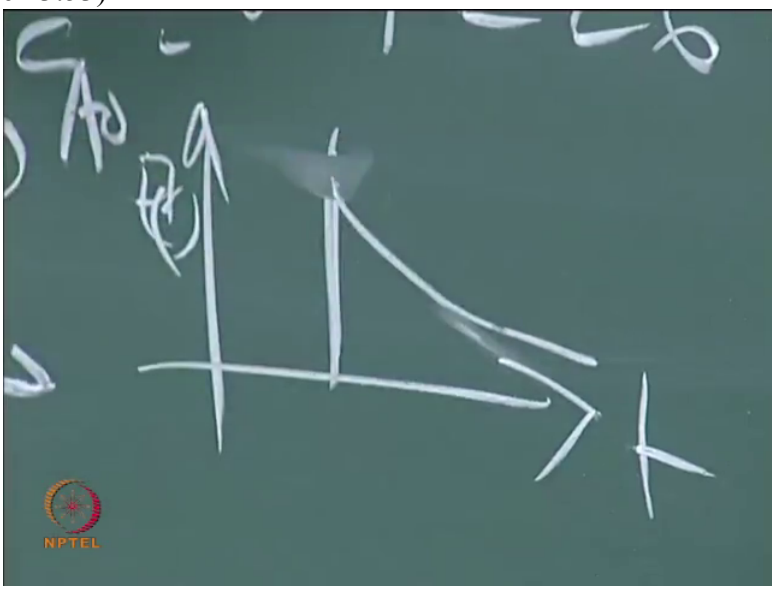

and ask you to calculate conversion, you can take some system with early mixing, you can take some system with late mixing, Ok good. Can you tell me in that four systems which one will be early

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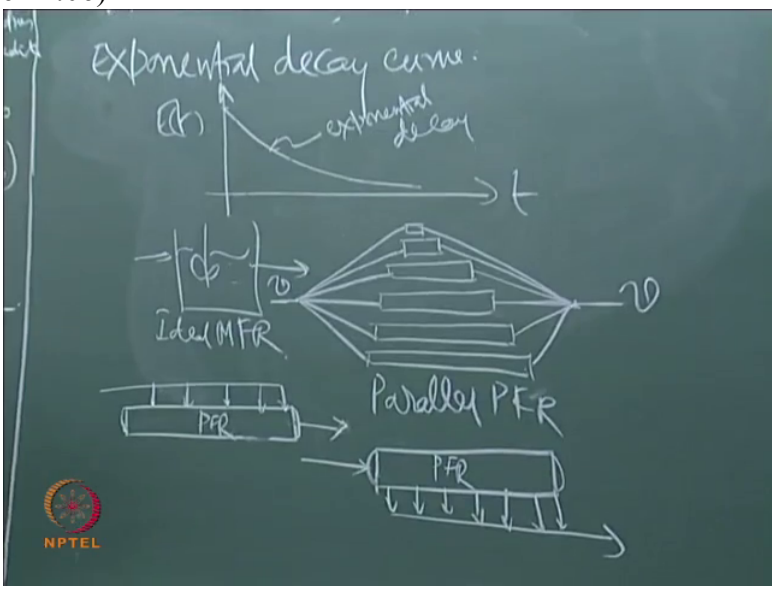

mixing, which one will be late mixing?

(Professor – student conversation starts)

Student: ()

Professor: Ideal?

Student: Ideal M F R is early mixing

Professor: Ideal M F R is

Student: Early mixing.

Professor: But you are forgetting another condition.

Student: Macro and micro

Professor: Yeah. That also, then you have to say;

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now you see. You are becoming more and more knowledgeable, no? So definitely yes, Ok.

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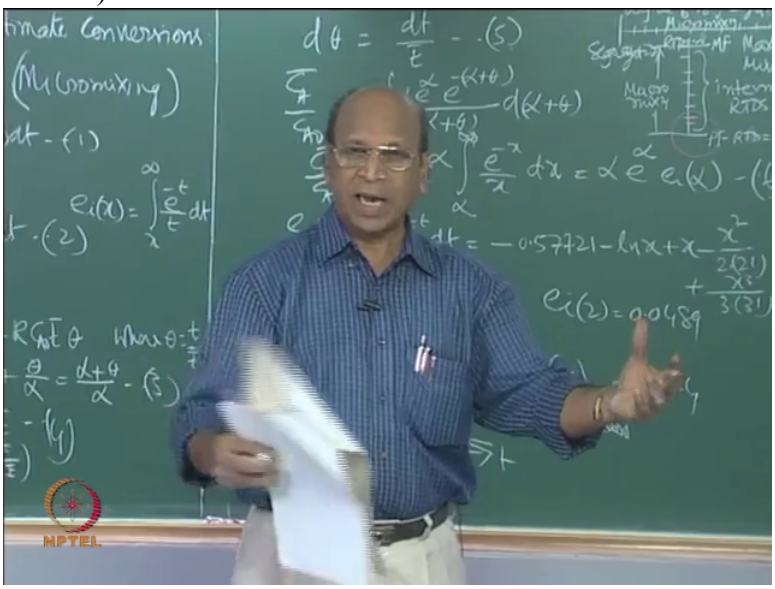

Because the question comes when she says that ideal M F R will give me perfect mixing, it won't give if you have macro fluid. So now you have to say that if we have micro fluid this system will give me.

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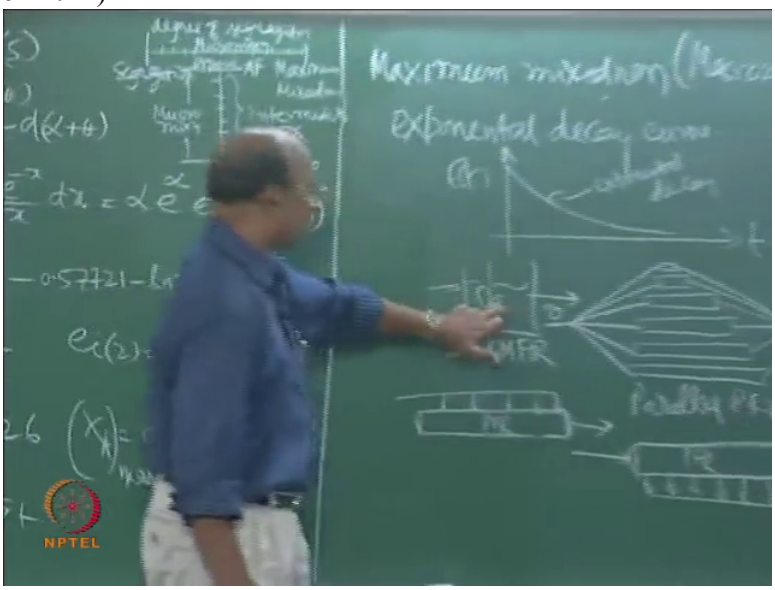

Ok, let us take first micro fluid and then discuss four systems. Ok, so which one will give me early mixing if I take micro fluid? This gives me,

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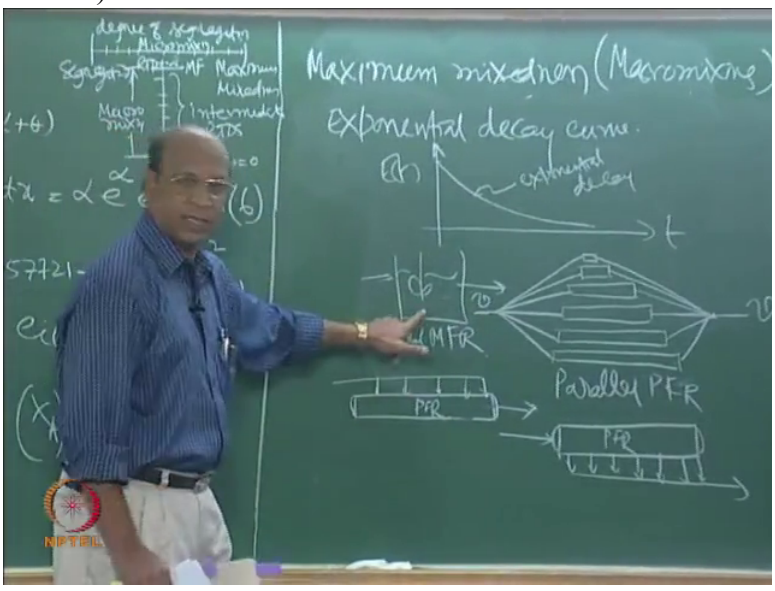

micro fluid this gives, this one?

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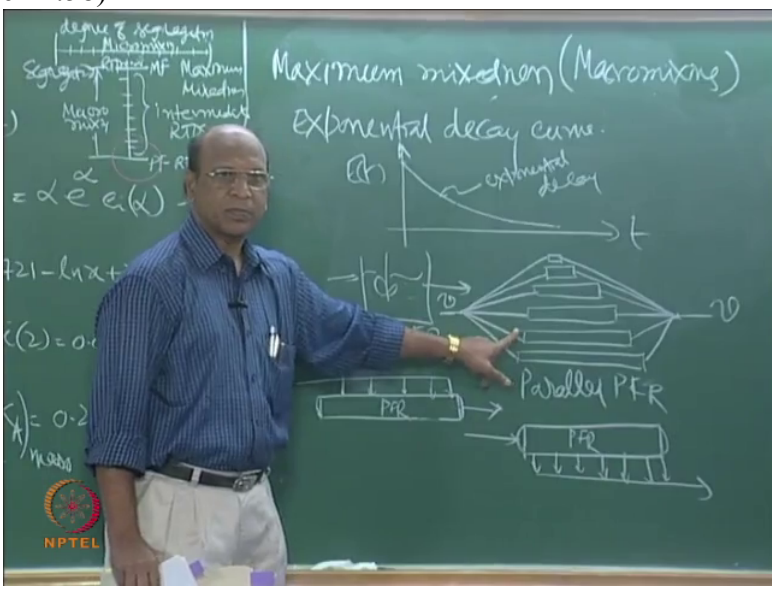

Student: Latest mixing

Professor: No mixing, Ok so here micro fluid

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behaves as if

Student: Macro fluid

Professor: Macro fluid. So that is the one.

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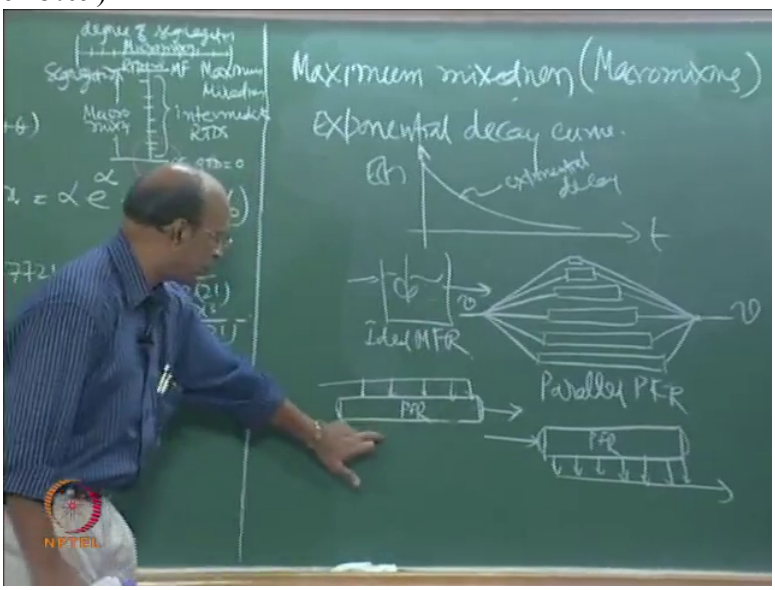

So this one?

Student: Micro

Professor: Yeah, this is mixing, early mixing or late mixing?

Student: Early

Professor: Yeah, why because these streams are mixing with other flow where they have different residence time distributions, right?

(Professor – student conversation ends)

So this one is early mixing, Ok, for micro fluid and this one?

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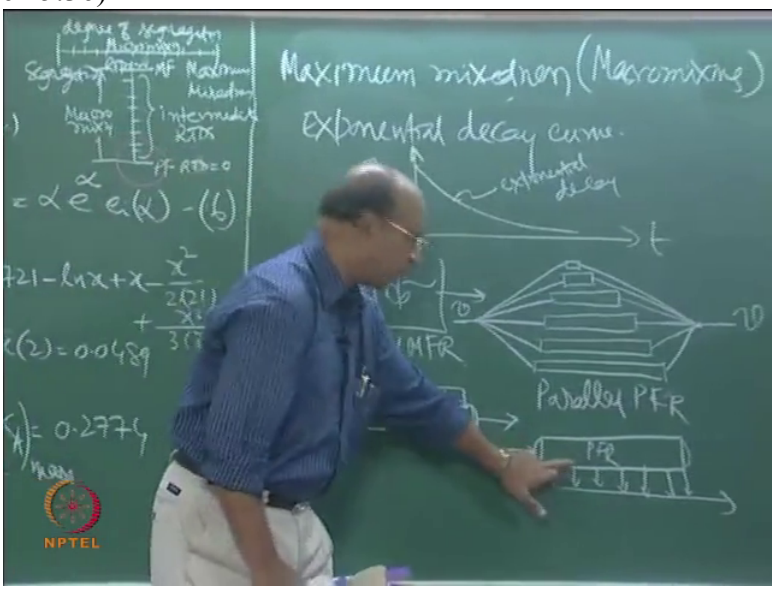

Late mixing because inside you are not disturbing at all. You are only simply taking out the streams and this is an ideal plug flow, right? This is an ideal plug flow. Simply you are withdrawing without disturbing. These are all theoretical.

This is what I told you that Zwietering paper that fellow really thought, I say. I really appreciate those minds. Why at least one millionth of that mind is not there for me also? Really. Because they simply sit down and then try to think and most of those times, most of the papers were single author because of that, late mixing

(Professor – student conversation starts)
Student: (laugh)
Professor: Ok, most of (laugh), Ok so most of the papers were single author papers because he is the only person sitting and thinking, that is all.
(Professor – student conversation ends)

And he gets the idea and then may be checking with friends and all that whether there is logical error, Ok and if there is no error then finally write a paper and then send. Wonderful.
So that is why, but we have to now still, we do not have to worry for this kind of ideal thing because when I have micro fluid,

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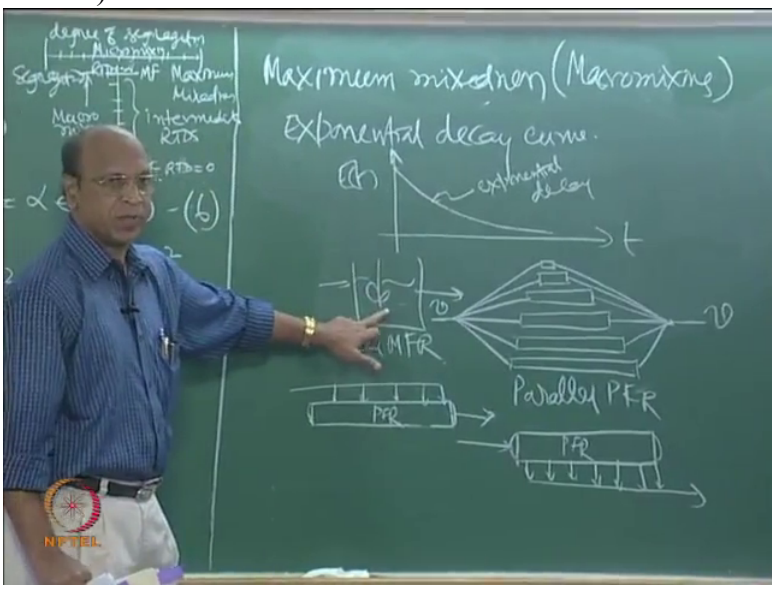

then I have to identify whether I have late mixing or early mixing and if it is late mixing, or here segregated flow, this is segregated

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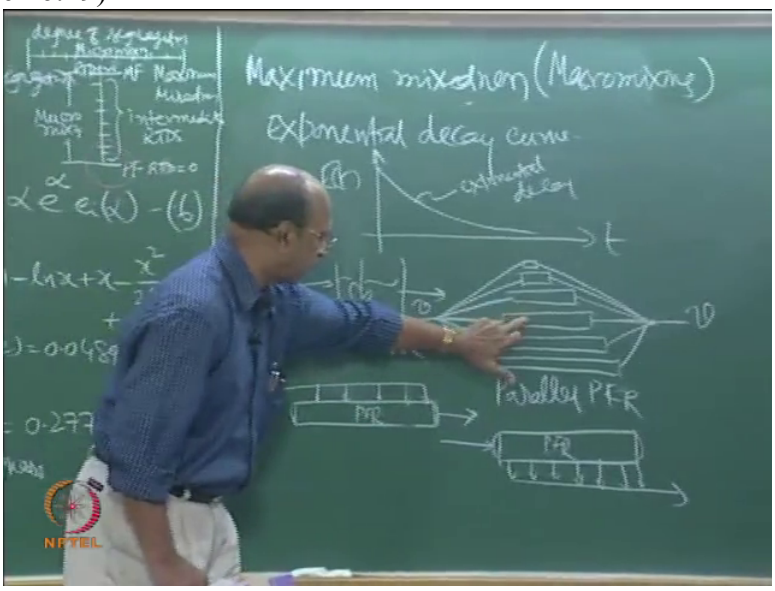

flow, this is segregated flow,

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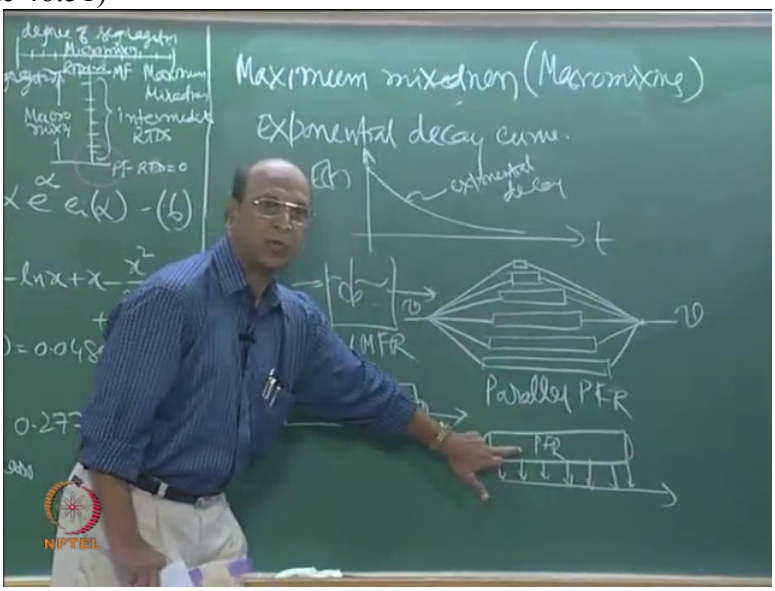

then I have to use this equation,

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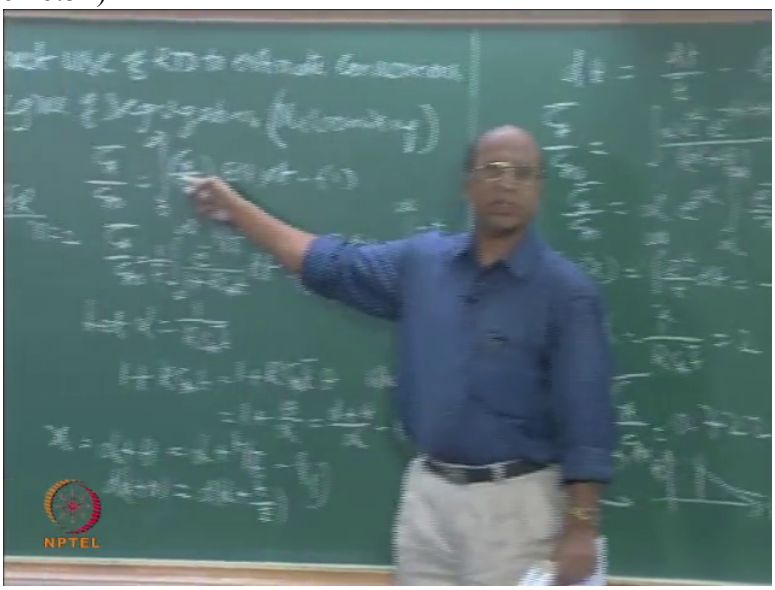

And in this case and in this case, I have early mixing,

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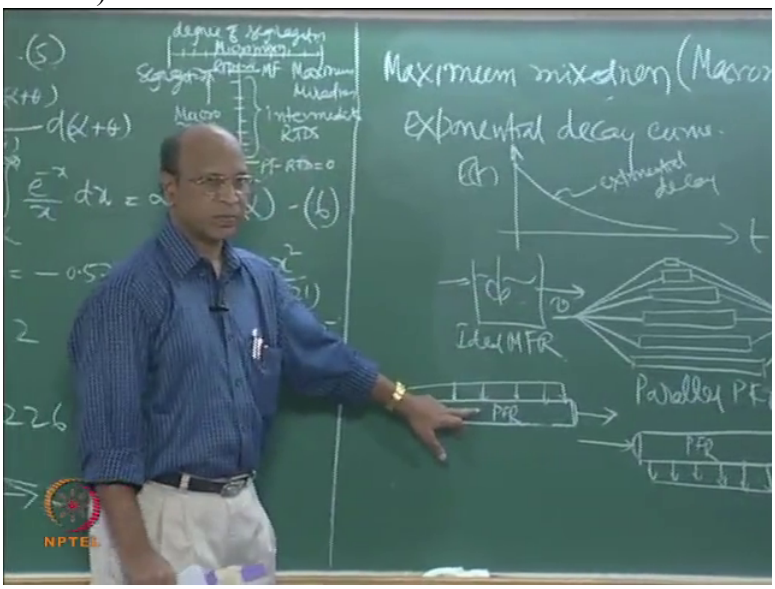

right? So here I have an equation,

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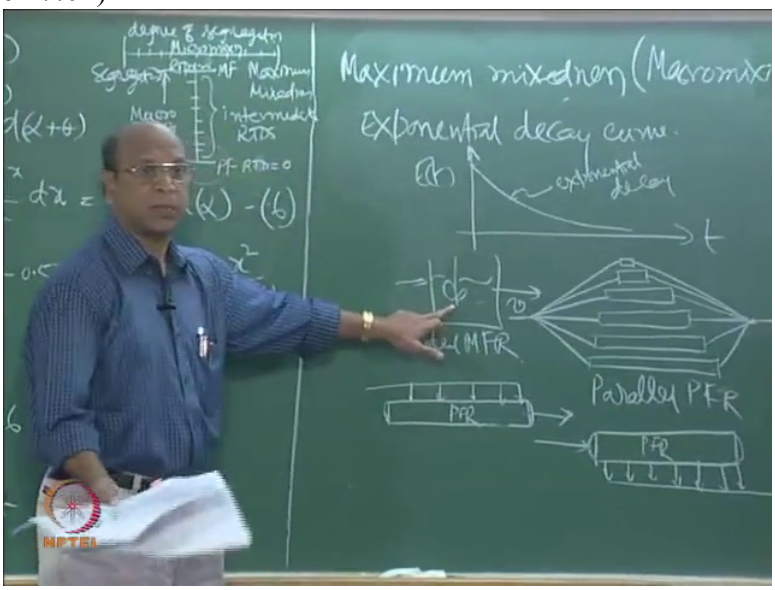

B Tech, if it is a first order or second order or third order, you know that normal, E by F A naught, that is X A by minus r A. That is for micro fluid. Please remember that. That is for only micro fluid. So I can find out that. That is no problem at all. Good.

So this is the one and yeah, Ok, now we have seen exponential decay for any other R T D, for any other R T D it is not easy to find out. But there is wonderful information which is not useful, but really information is good. useful in the sense that you cannot use them for calculating conversions because they are very, very complicated, so that is why people are, it is not popular, those papers. There are few papers Levenspiel also gave in his chapter.

And any kinds of intermediate R T Ds that means some late mixing and some early mixing Ok some late mixing and some early mixing. So these two can be managed by using only these two systems.

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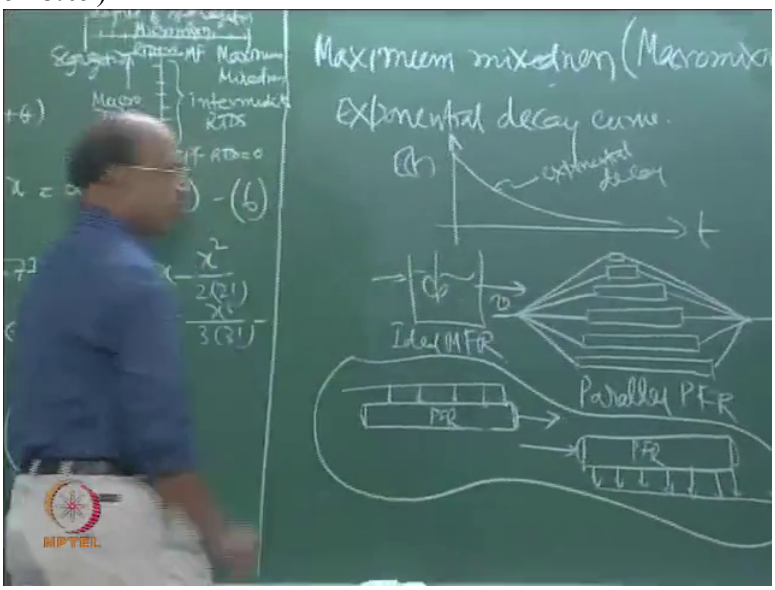

So this is early mixing. This is

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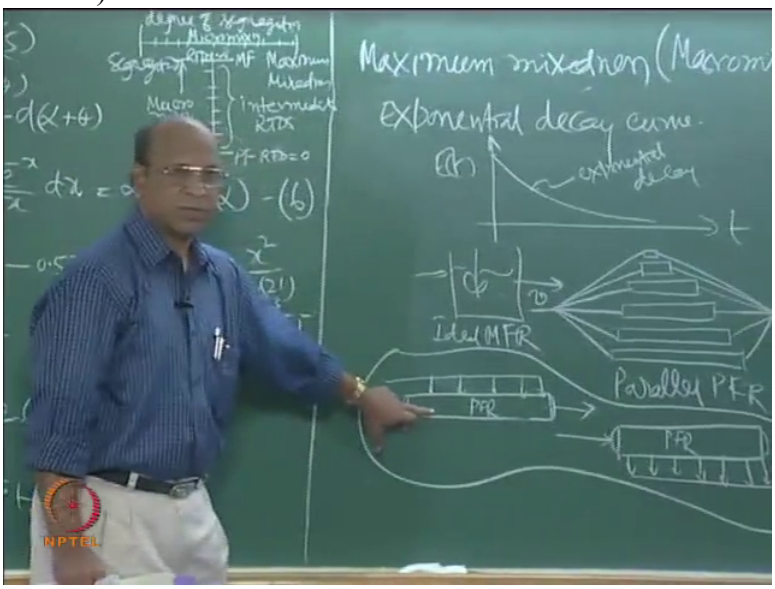

late mixing,

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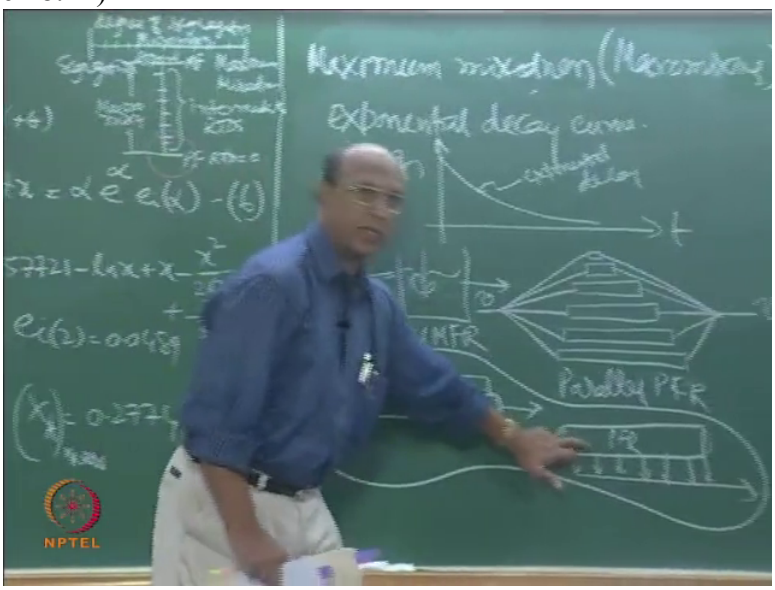

right?

So that means let me say that I have few packets and few individual molecules. These individual molecules will give me early mixing. Packets will give me latest mixing that is possible. So in a real system how do I know how many are there? How many packets are there? I do not know.

But if there are really some packets and then some molecules now you imagine this model.

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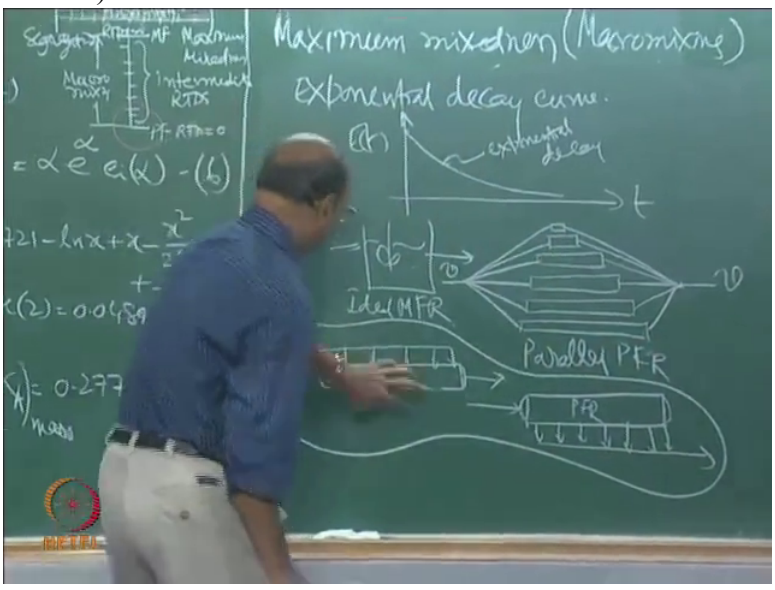

You see individual molecules will give me early mixing. That is micro fluid. And packets will give me the late mixing. So you take this is 30 percent, this is 70 percent.

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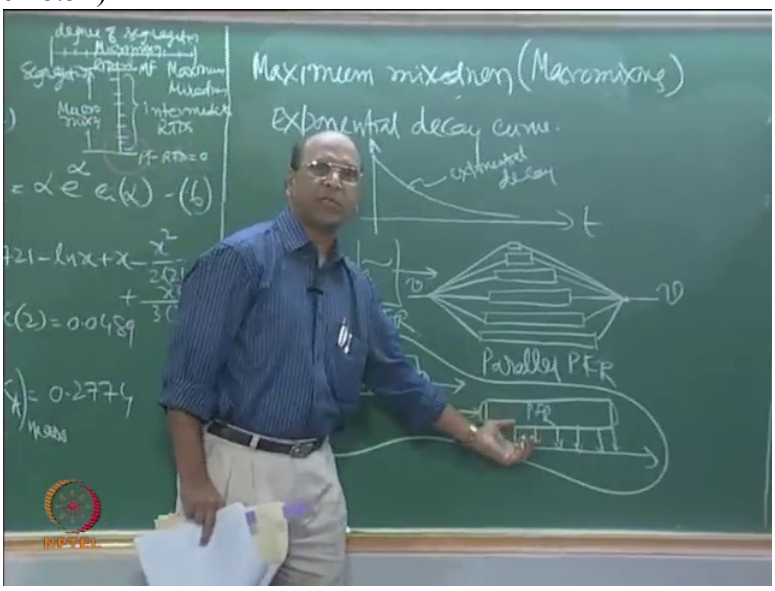

And then calculate overall conversion.

Right like either parallely you can put or series you can put. Because these 2 systems, either series and parallel, and then you calculate by a fitted parameter called the percentage of, the say the number of packets and number of individual molecules. In terms of some percentage. Ok. 10 percent of the fluid is in packets. 90 percent is in individual molecules.

That means where are you? On this scale where are you? 10 percent, I said 10 percent packets and 90 percent individual molecules.

(Professor – student conversation starts)
Student: Maximum mixedness
Professor: Yes, maximum. Only 10 percent packets and 90 percent.
(Professor – student conversation ends)

Similarly

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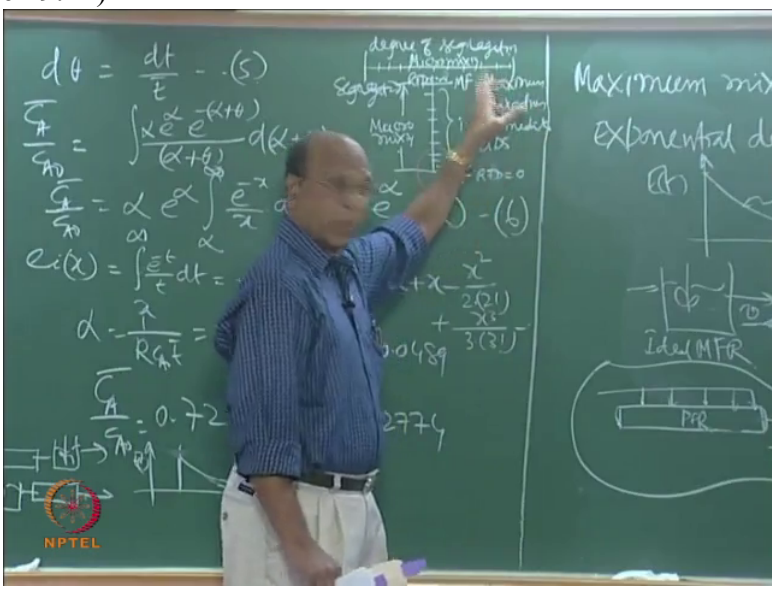

you take this one as 90 percent,

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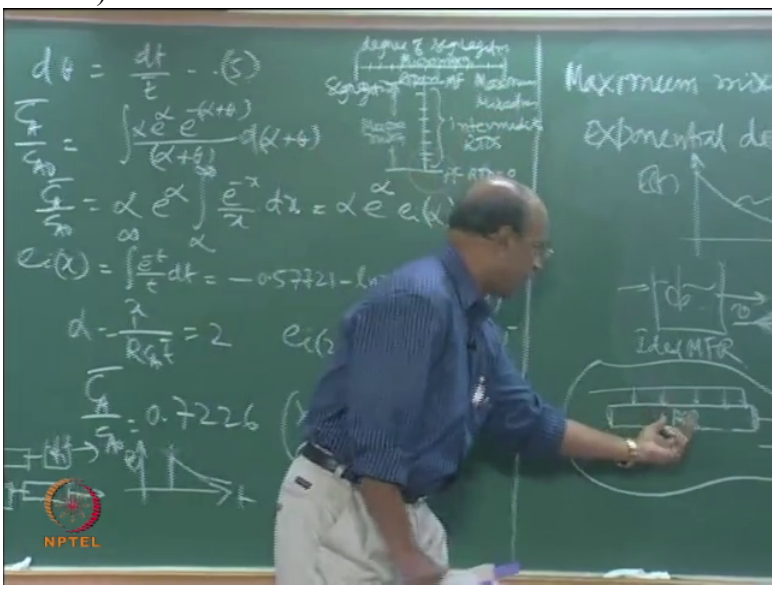

this is as 10 percent

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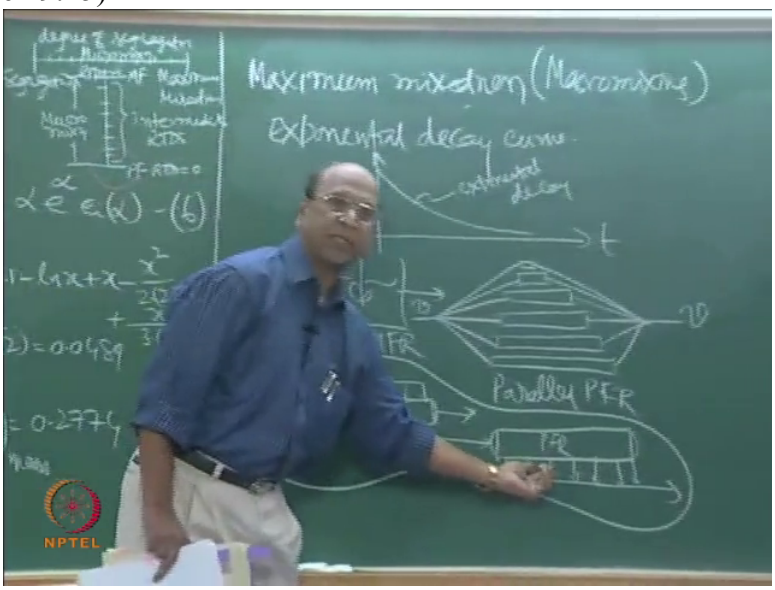

And you calculate conversion, do the experiment, find out whether that conversion is same as this. If that is same, by hook or crook you got the values so then it must be same. That is what what we talked.

So that is why, other than the extremes we are not doing anything but you should know how the extremes also should be manipulated using only these two

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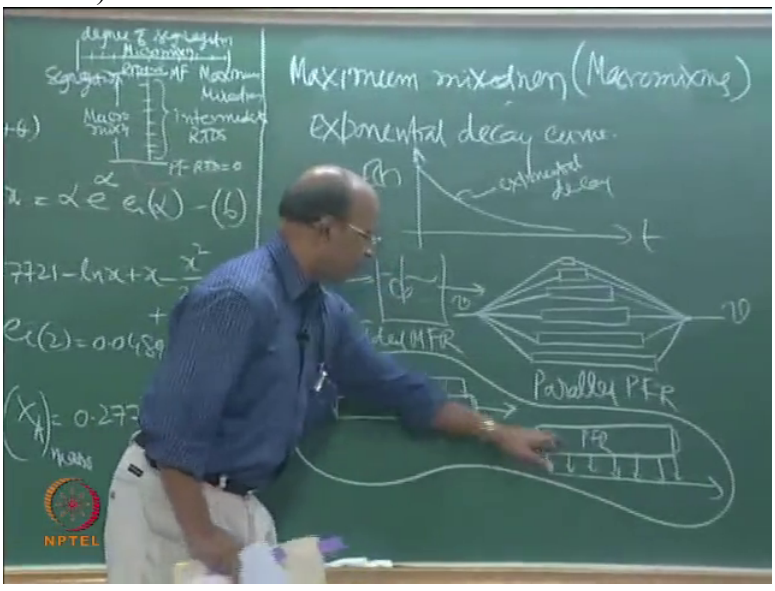

systems. So this is ideal plug flow

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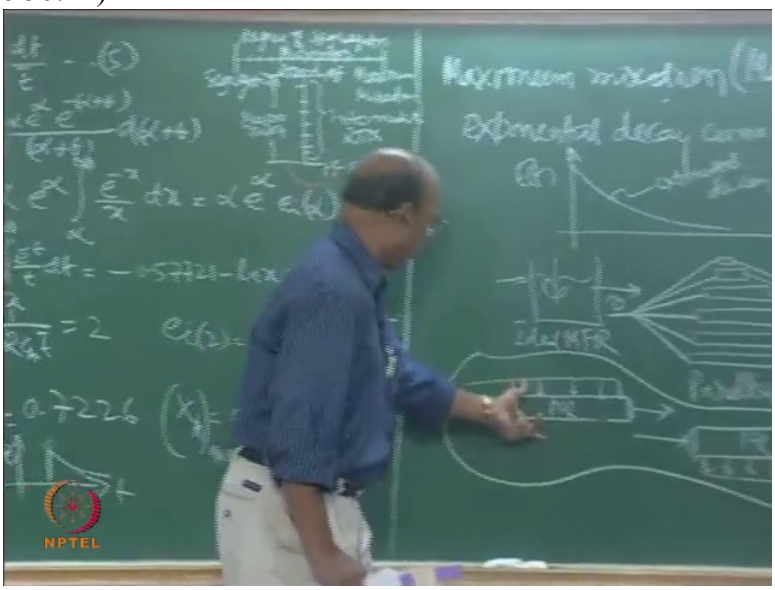

and ideal plug flow but this gives me early mixing, that gives me late mixing but both the systems I can manage such that my external, my actual conversion is matched with some adjustment between these two things.

You know, flow also is a parameter. How much is going in that, how much is going that is one parameter. And fraction also is one parameter. So both you can just try and then try to find out. It is very difficult that is why none of us are trying to do that. But knowing information, there is nothing wrong. Ok, good so that is what.

So this is what is completed R T D but only thing I just wanted to tell you was the other one. What is that? I left it because I think some latecomers may also lose this. I think I will again....So this is clear no?

So we have defined two components of mixing. One is micro mixing, one is macro mixing. Ok. Micro mixing gives me degree of segregation. I have to worry only when I have mixed flow reactor. And that gives me macro fluid and micro fluid some difference. Whether it is first order, second order, sorry whether is it is second order or half order.

For first order it is same. Absolutely no problem, Ok. That is why in sixth chapter of Levenspiel we say that if you have first order, any order of you know plug flow or mixed flow for n equal to 1. So reason is this, good.

And then we came to maximum mixedness, this scale,

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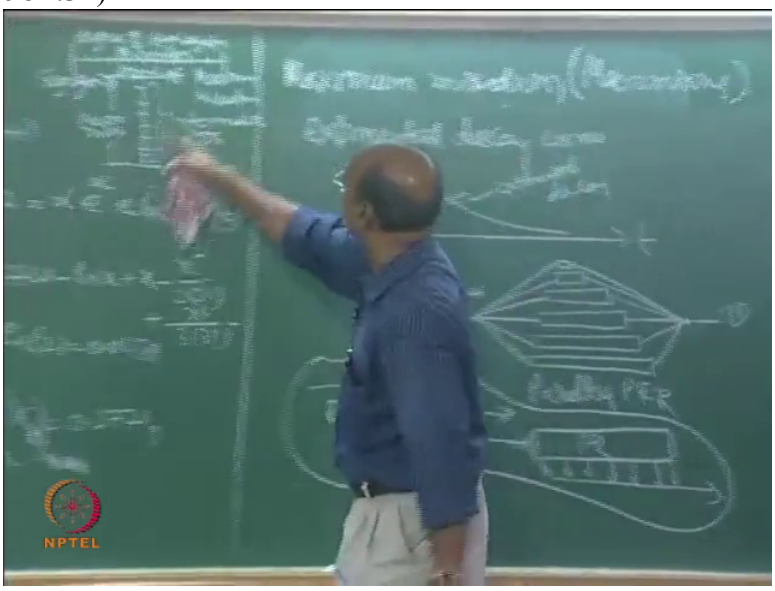

P F and M F and this R T D equal to zero distribution we discussed. That is possible only for P F R, right. So P F R means again I do not have to worry about whether I have macro fluid or micro fluid. Or segregated flow or you know early mixing or late mixing. Because both will give me exactly the same conversion.

And in exponential decay when I

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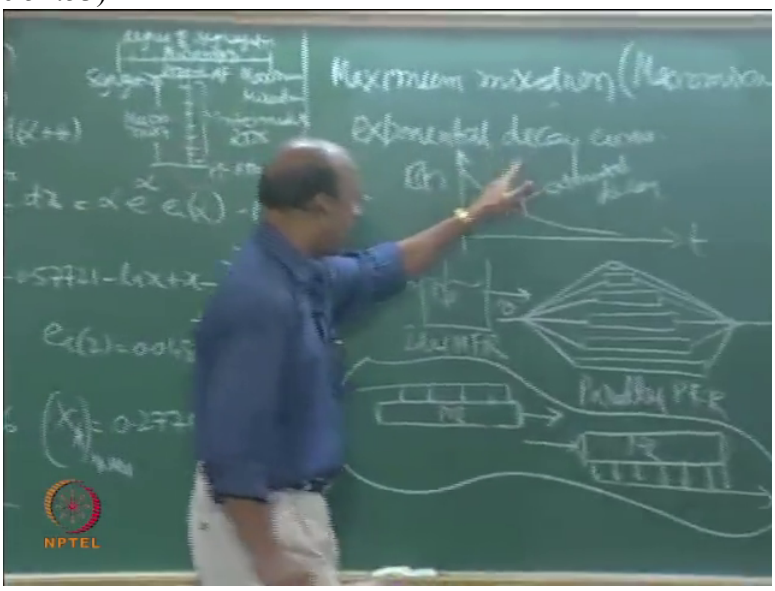

have I can have any number of possibilities. But you have to identify them, which is late mixing, which is early mixing. And if it is the latest mixing that is possible, we have this equation, right? And if yeah, if this is

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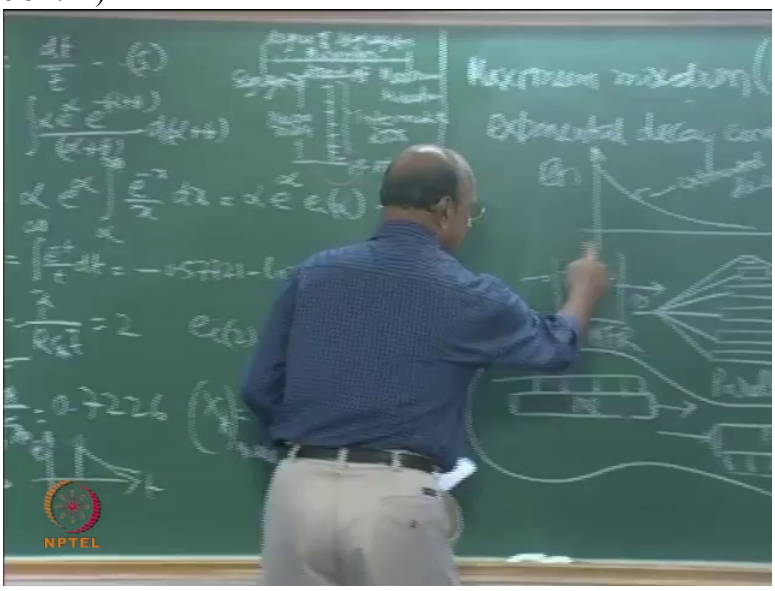

M F R alone, we already did it. It is B Tech.

In between any R T D if I take, in between

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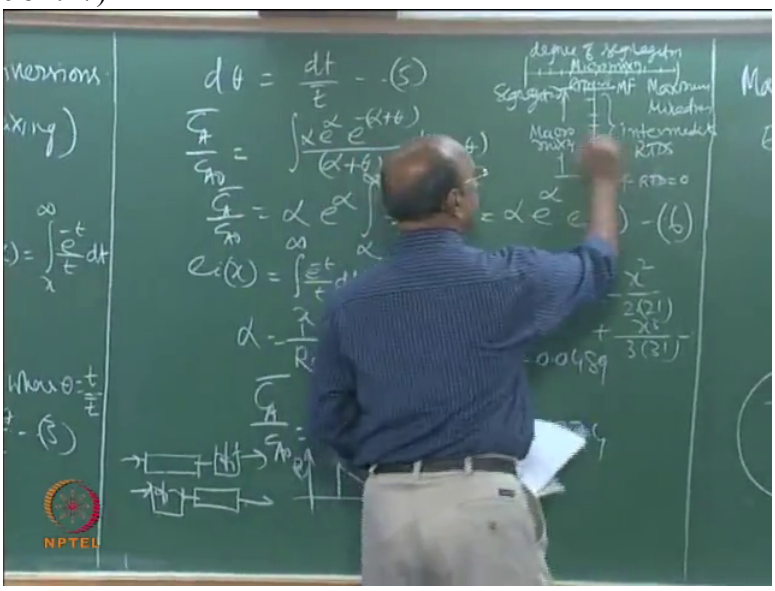

any R T D I take, Zwietering has given that equation. That equation I will just write. We are not deriving that. That equation I will give you. Yeah. Any R T D. Ok. This I can remove.

So now we have seen two extremes but any R T D in between,

(Refer Slide Time 52:44)

any R T D between P F and M F equation given by Zwietering, I sent that Zwietering equation to all of you. This is d C A by d lambda equal to minus r A, directly he has calculated conversions because our idea is direct use of R T D estimation,

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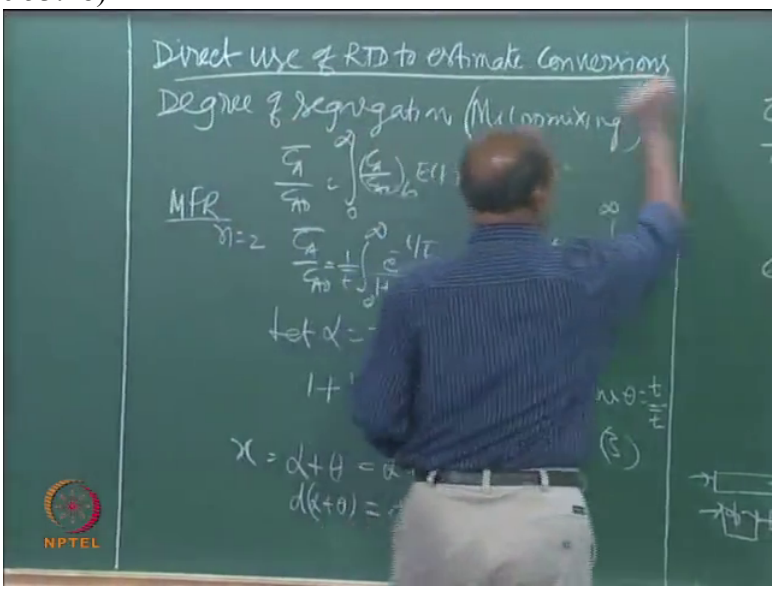

you know to estimate conversion. Ok, plus C A minus C A naught E lambda by 1 minus F lambda.

So this is the equation and the boundary condition is

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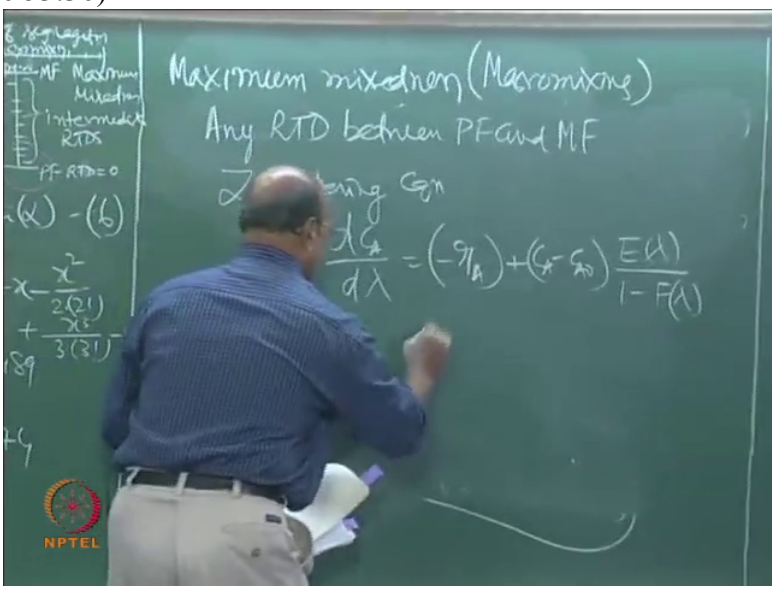

lambda equal to infinity, C A equal to C A naught.

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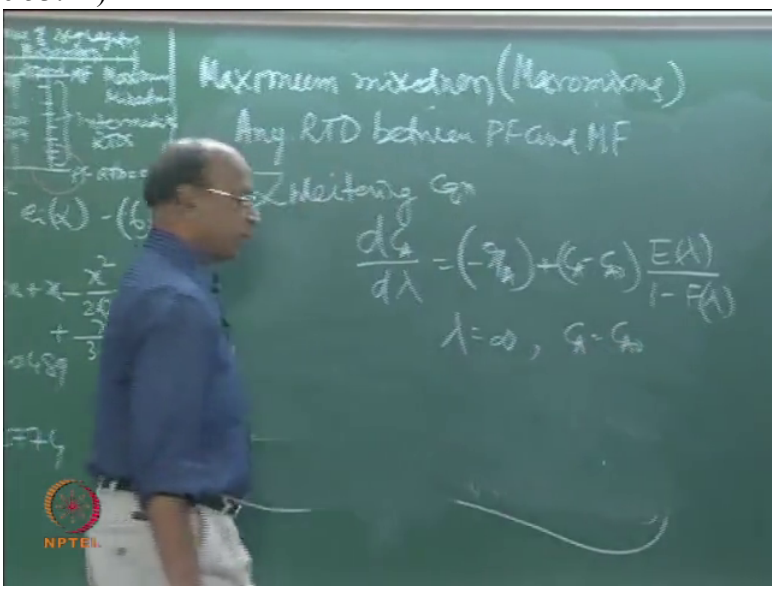

Lambda equal to life expectancy. That is why the boundary condition lambda equal to infinity means, do I know what is the life expectancy in the general reactor when the molecules are entering?

Do I know that value? No. But definitely it is not zero, correct no? Definitely it is not zero. Because it has to enter the reactor and then come out. Unless we have 100 percent bypass. 100 percent bypass means you do not have any reactor. Because it is supposed to go into reactor, it is not going into reactor. So that is why we take that value.

But lambda is, lambda equal to

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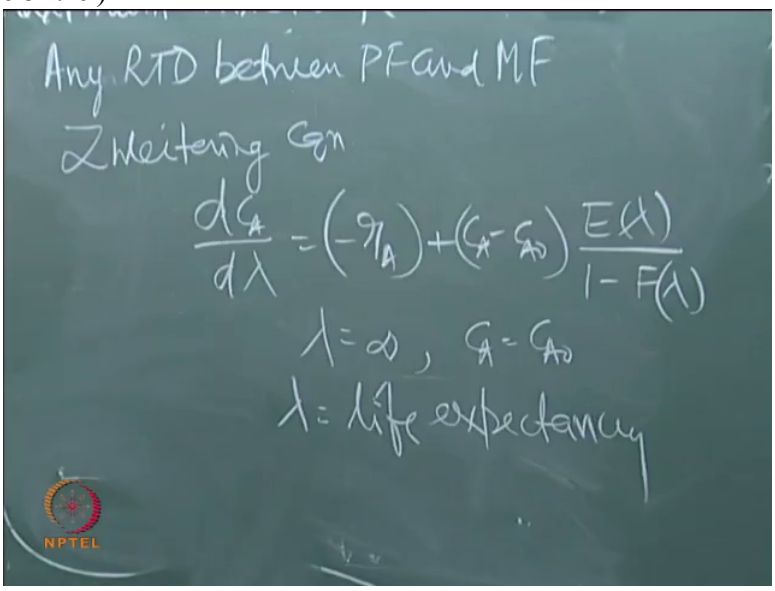

infinity is one of the largest value you have to take and then slowly solve that. That is why I told you it is not very popular. So which value you have to take and you have to solve this particular equation.

And for first order, yeah this is

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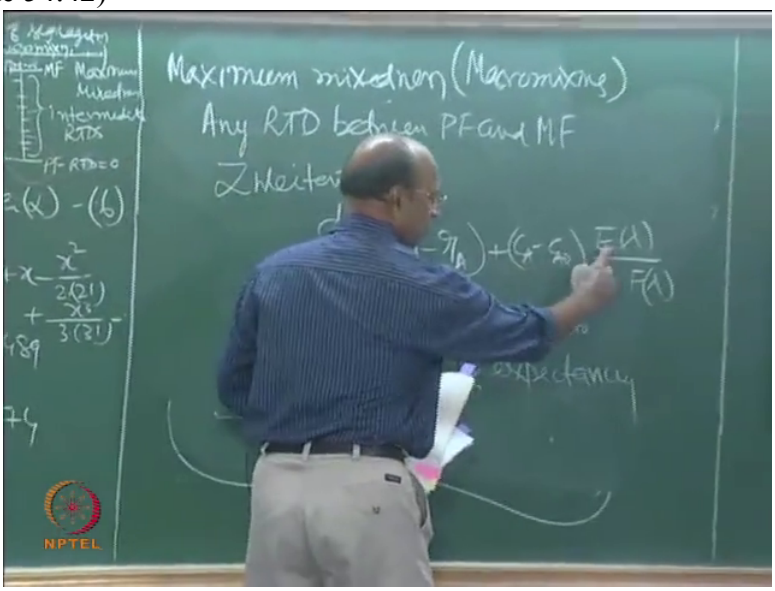

E lambda is again, you know the exit age distribution function and F lambda but in terms of life expectancies. In fact I told you in the beginning for E t, it is also a probability, a probability function, correct no? You measured there at the outlet saying that fraction of material coming between t and t plus delta t is E t d t. The same thing I can also tell in the beginning itself. Correct no?

So this is the probability. The probability is this E t delta t, the fraction of material which is coming, which will come between time t and t plus delta t will be E t d t. But where you are telling? Normally we take only at the exit because we would like to calculate conversions.

But same thing can be imagined in the beginning also as if that much fraction is going to come only between second minute and third minute, or fourth minute and fifth, sixth minute or seventh. So that is why. So this is not a difficult problem to understand. So that is why, but this is 1 minus, yeah what is 1 minus F lambda?

(Professor – student conversation starts)
Student: I lambda
Professor: Of course t bar I lambda will come there, Ok. So anyway we do not write normally, so this is the one. For first order also you can solve and you can get immediately, for first order M F R. First order P F R. One can easily solve this, Ok. So that means minus r A into k into C A and what is E lambda and F lambda for ideal C S T R? You know the equation.
(Professor – student conversation ends)

That equations we can correspondingly put and then one can solve, Ok. Good. So that lambda to understand a little bit, then little bit,

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Zwietering defined a function called residence time. Ok, I think I will write, Ok, let me write, residence time, residence time t

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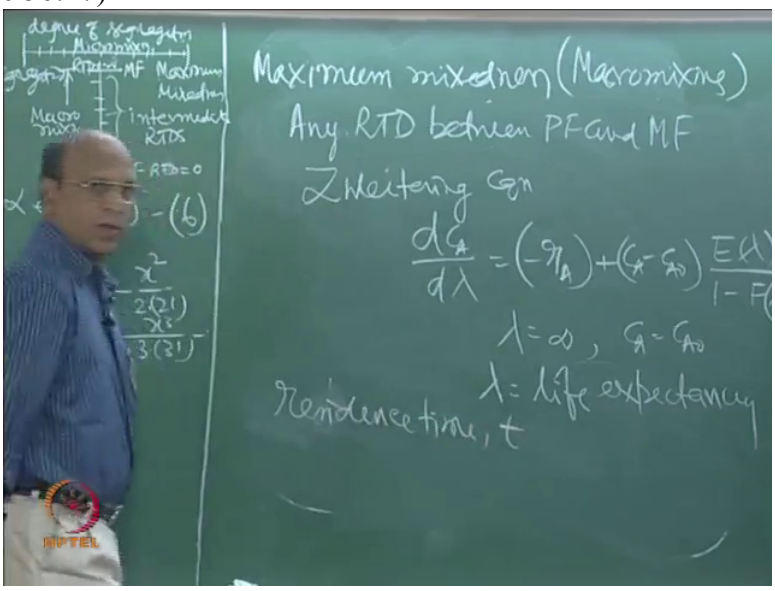

Ok can be imagined as alpha plus lambda, this is lambda only, gamma. Gamma is this, Ok. Alpha plus lambda

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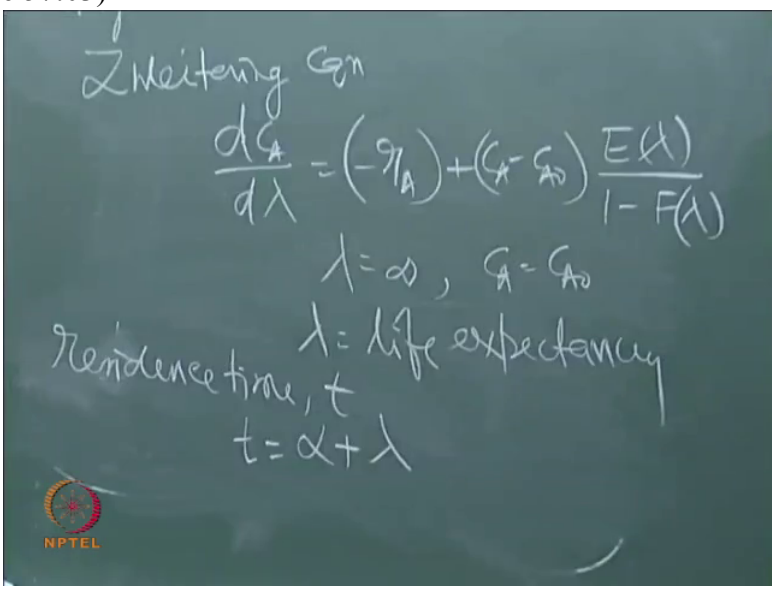

where t is the residence time.

That means any molecule which has entered definitely will spend some time to come out. Let us say it has come out in 5 minutes. So somewhere, 2 minutes before if I would have looked into the reactor, then I would have seen that it has 3 minutes age alpha and remaining 2 minutes is life expectancy.

Again easiest way of understanding is our own age. The moment we come to this world, our age starts. So, and life expectancy we do not know. Assuming that a person is living only for 45 years. So when you look at him at 20 years, life expectancy we can now say that 25 years left.

But only in ideal particle will have, yeah, every age will be correctly associated with the lambda. That means definitely I know. If a molecule is spending 1 minute, total is 10 minutes, then 9 minutes definitely that will spend. And I also know that if a molecule spent already, age 3 minutes, then we have another 7 minutes to go, but all other real systems you can never expect this lambda, right.

So that is why what he says that if you imagine that I have the reactor at this point, right? Just before entering, alpha equal to zero,

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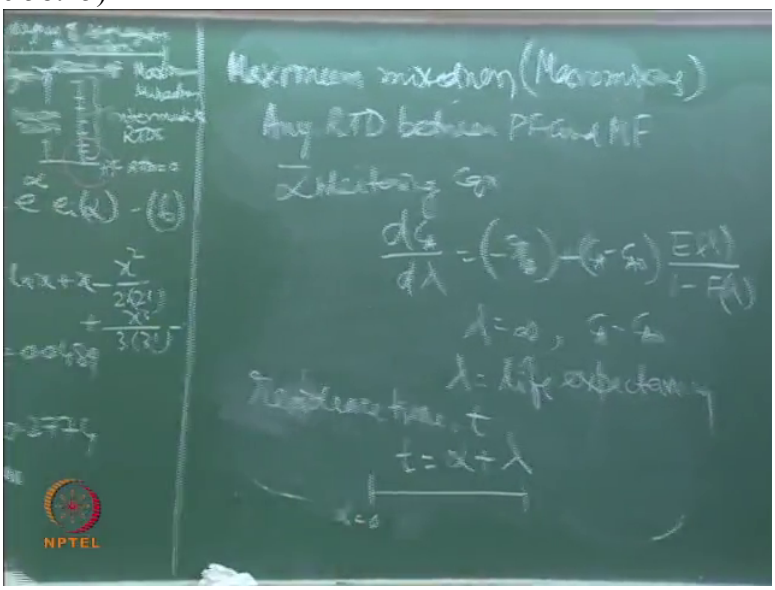

correct no? Just, about to enter. Age, it has not yet entered, just zero plus the age equal to zero. And when it is just about to leave, lambda equal to zero. Correct, no?

So at this point

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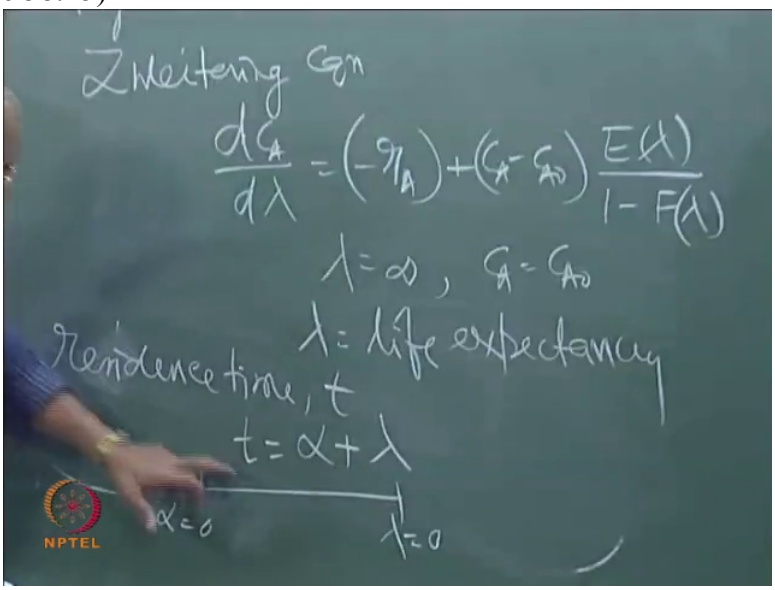

have alpha equal to t, t is the residence time. And at this point, alpha zero you have the life expectancy. You do not know how much but still you have the life expectancy. What he says mixing is, it is the kind of transformation from; that means all the molecules alpha equal to zero, here. All the molecules have alpha equal to zero. So I can call this, there is a uniform environment of molecules with alpha equal to zero, right, uniform environment. All molecules will experience the same thing. That is what uniform, Ok, good.

At this point I have different ages but life expectancy equal to zero. That means again in this corner we have another uniform environment called age. Correct, no? Because age, it has already come out, alpha.

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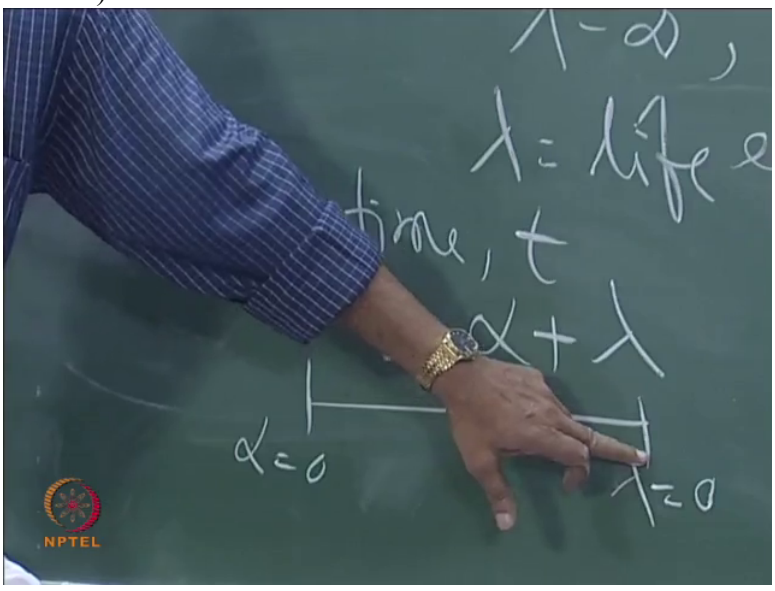

Alpha of course, alpha equal to t because residence time, right. So he says that some kind of transformation is taking place from this uniform environment where

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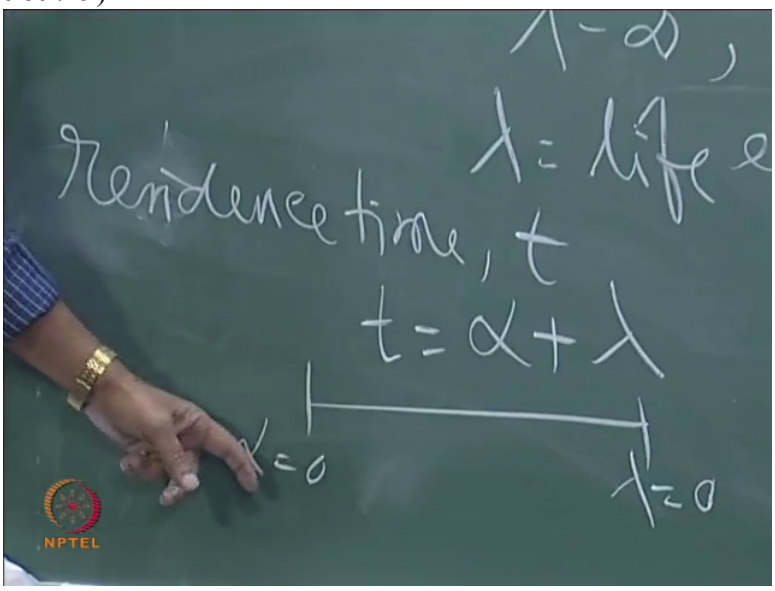

alpha equal to zero to life expectancy equal to zero.

So if it is as quickly as possible, if the transformation is as quickly as possible, then we have what is called, it is taking as quickly as possible, we have what is called maximum mixedness. That is M F R.

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Ok. No, no, macro mixing is the overall scale. We are talking about only

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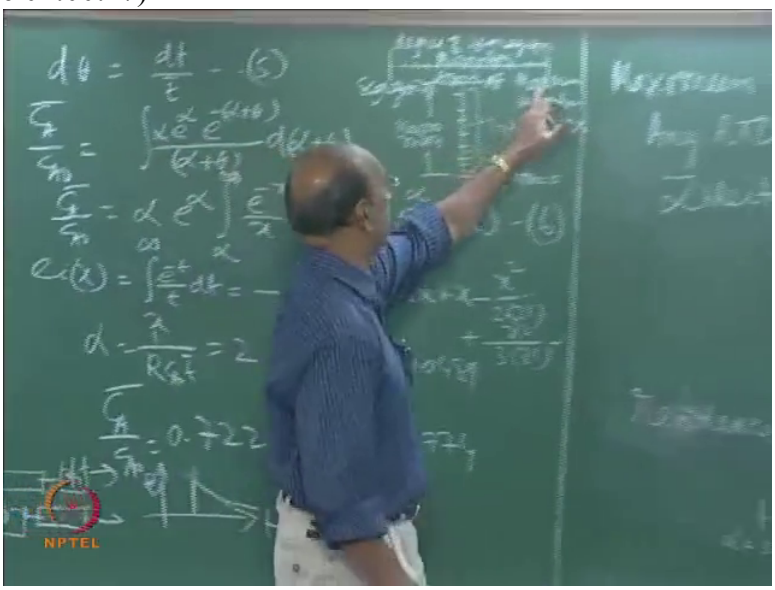

this point, maximum mixedness. Ok.

Once more. So I have a

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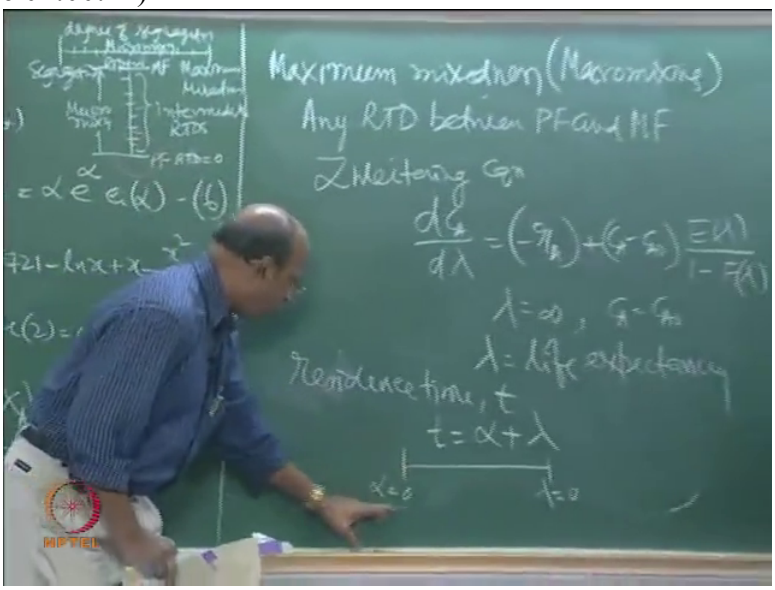

uniform environment here where alpha equal to, yeah where alpha equal to zero. And I have another uniform environment where lambda equal to zero. This is zero

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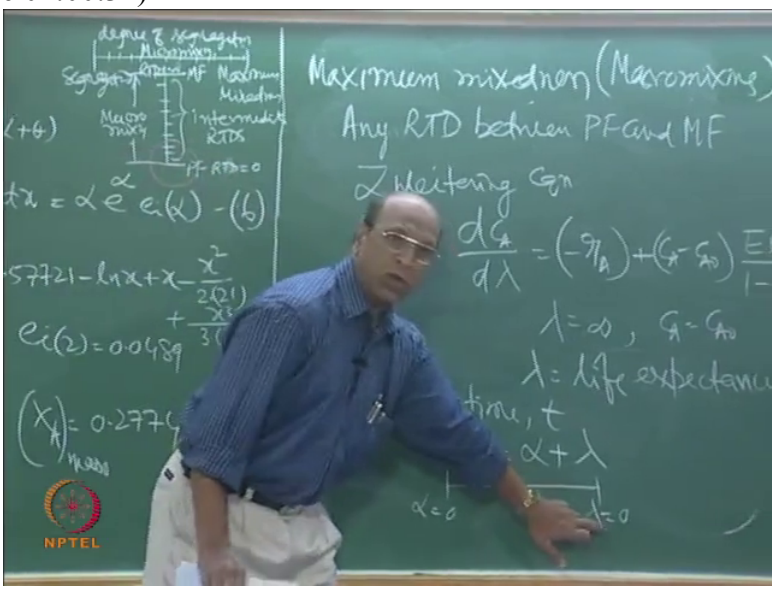

life expectancy and this is zero age environment.

Now if this

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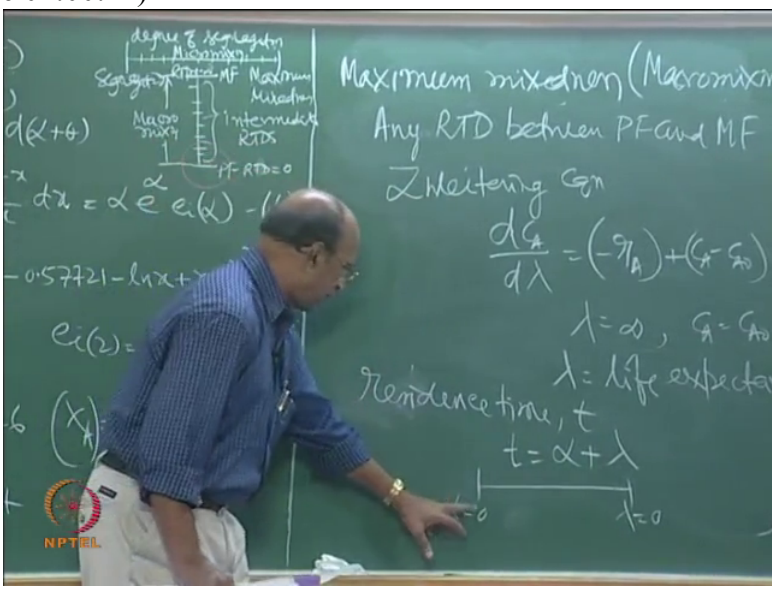

zero age environment has quickly going to lambda zero environment, then it must be because of maximum mixedness. Otherwise it cannot go, no? It is immediately taking place. Otherwise if it is plug flow what will happen? That at least you understand.

If it is plug flow, each and every particle must spend exactly

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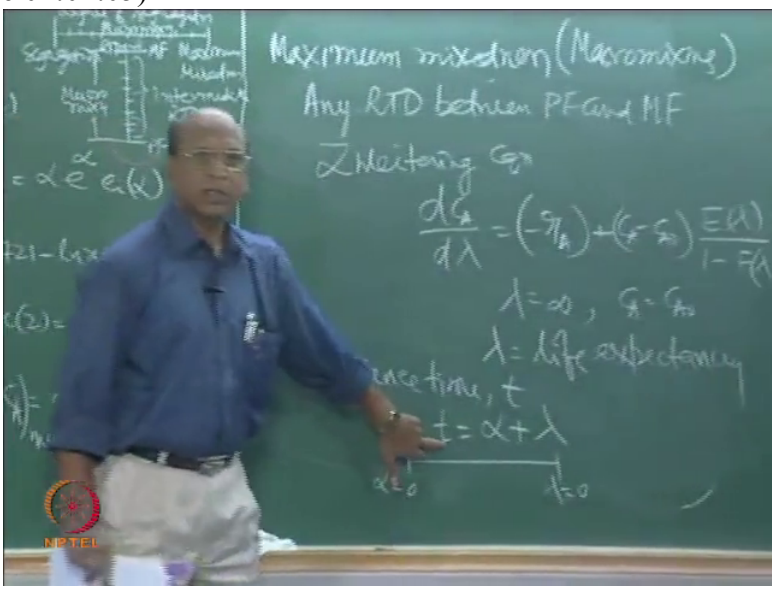

time t. We are talking about individual molecule, time t, right, it is not t bar, it is time t. But t bar equal to time t for plug flow reactor that is one.

So that means in any other reactor if the transformation is very fast, if it is the quickest means that should happen

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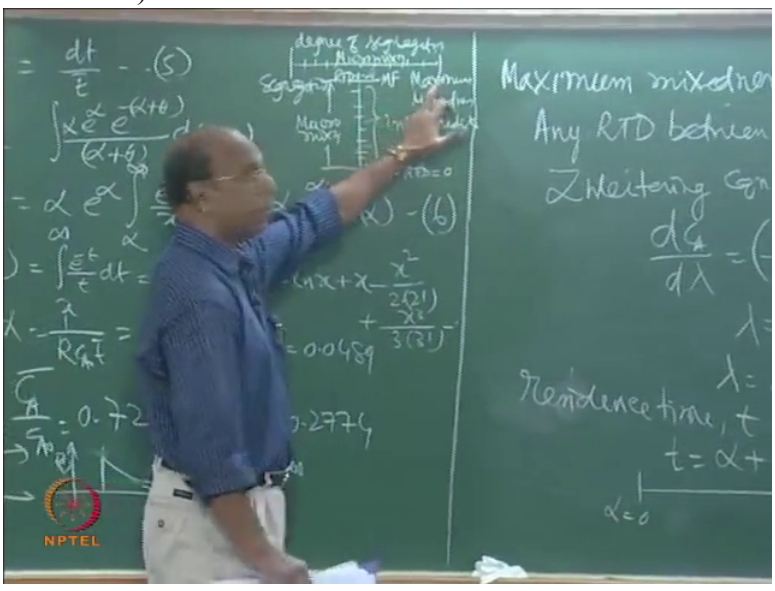

only maximum mixedness. And that is possible only for macro fluid and M F R. Ok. That is why he has used this lambda

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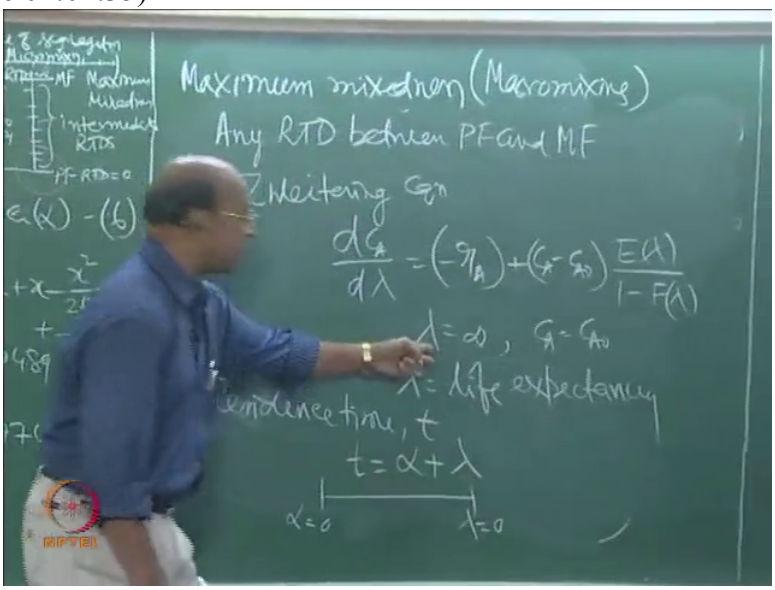

in his equation. He discussed this first and then derived this equation.

And the derivation is given in

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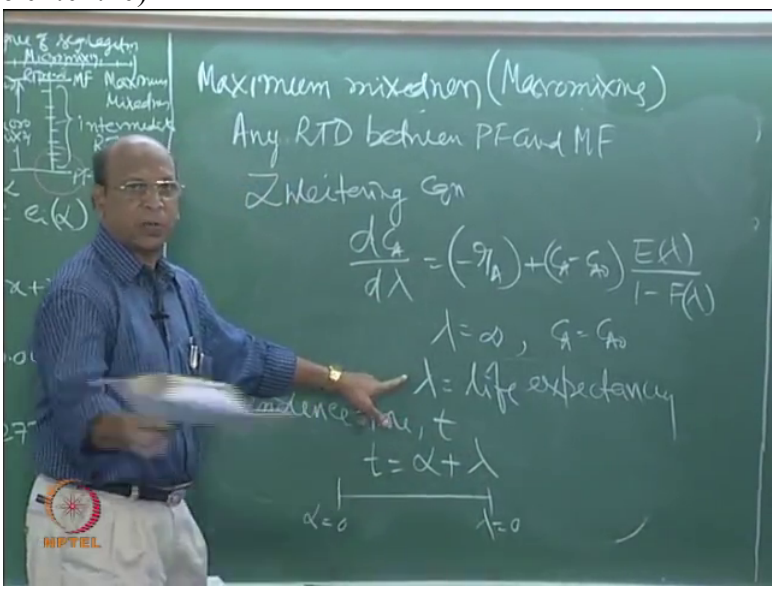

Fogler which I am not asking. That is just for your information. Ok, for examination you do not have to worry. So this lambda life expectancy is, no from here, that means if I have alpha zero, t is lambda, right. Here. Alpha zero,

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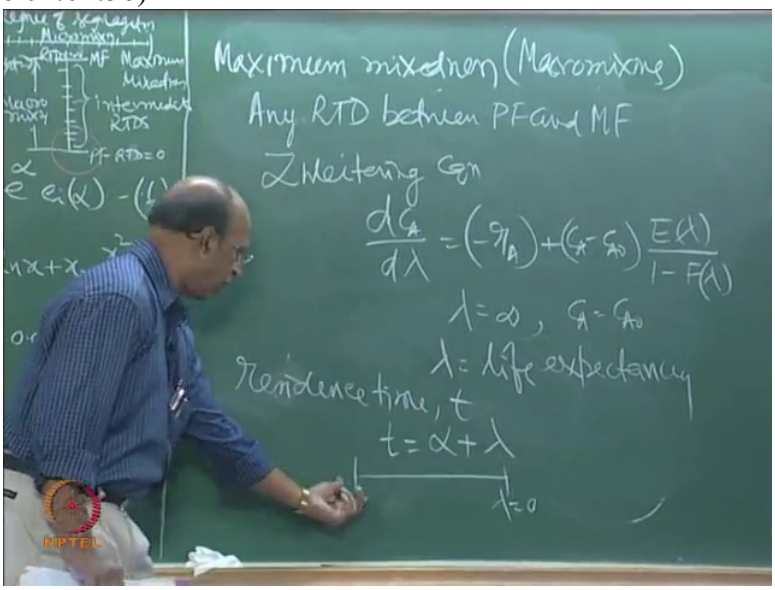

t is lambda at this point.

And at this

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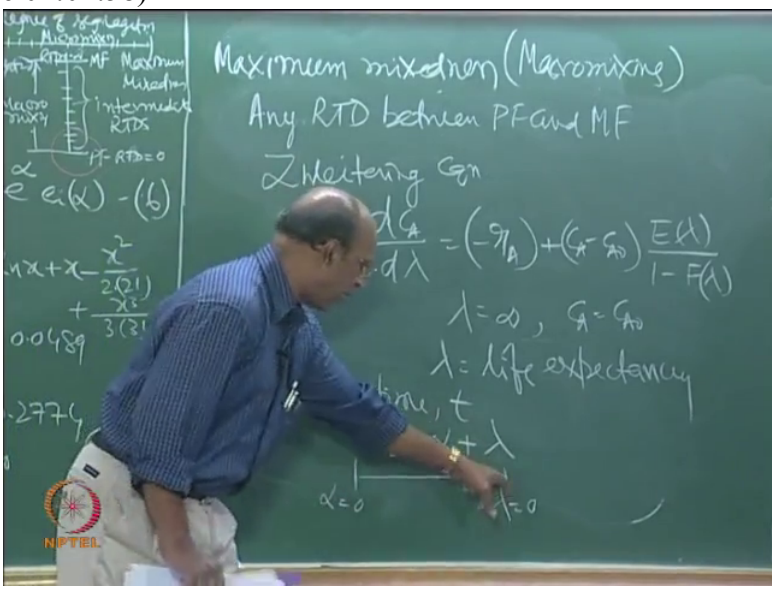

point when I have lambda zero, t equal to alpha. So from this lambda transformation to alpha transformation is, if it is very quick then we have what is called maximum mixedness. If it is delayed as much as possible, excellent, that is the other extreme, segregation. Ok, as much as possible means within the reactor that is not happening. Then you have segregation.

So based on that he has now derived that equation and that equation is only for your information, good. I think this is over. And I think there is a very nice problem given in

Levenspiel. That is a beautiful problem in third edition. In second edition also it is there. That is problem number 16 point 1, 16 point 1. That problem I think all of you can go through that but I think there is, it is very easy to understand because we already discussed most of it there.

The problem

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is something like this. Ok. That is a very beautiful problem. Levenspiel, that problem is really wonderful problem, right. So the problem is given as, this is 16 point 1 I told you, the problem.

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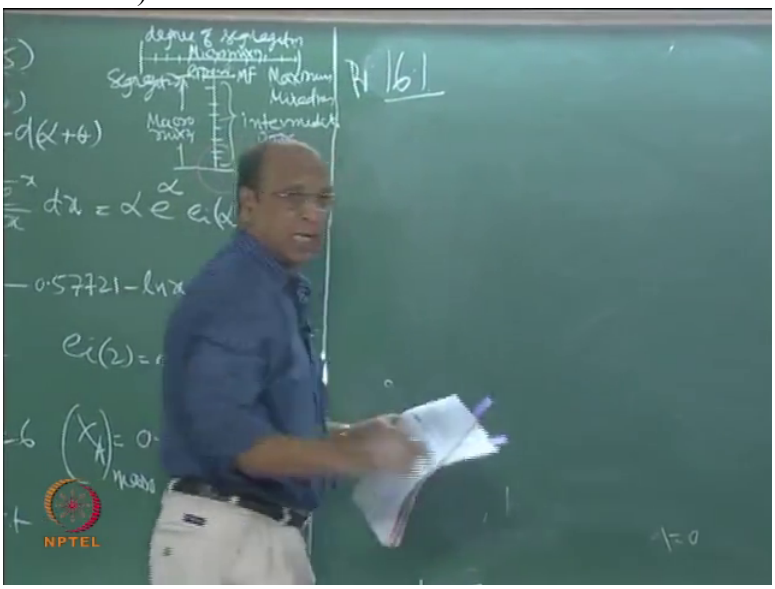

It is not problem actually. It is solved example. Example.

The problem is given like this. E t curve, E t versus t. And we have here, the exponential decay. Yeah, exponential, right, yeah. So, of course, the area equal to 1 and all that. Somewhere here I have t and this is t bar by 2, Ok. What are the systems you may; you know this is only exponential decay what I have.

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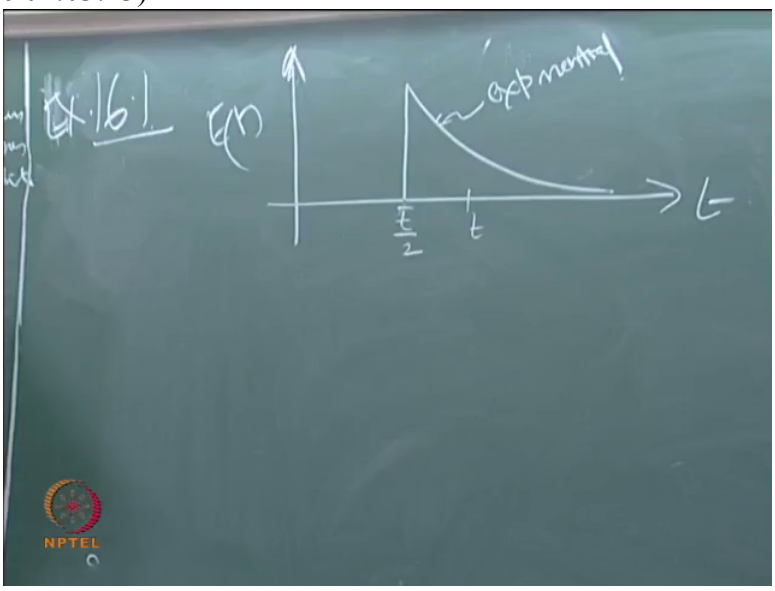

This is only E t versus t curve only what I have.

Now what are the possibilities I can imagine here? The first one is ideal P F R one, a is sorry not ideal, mixed flow by P F R,

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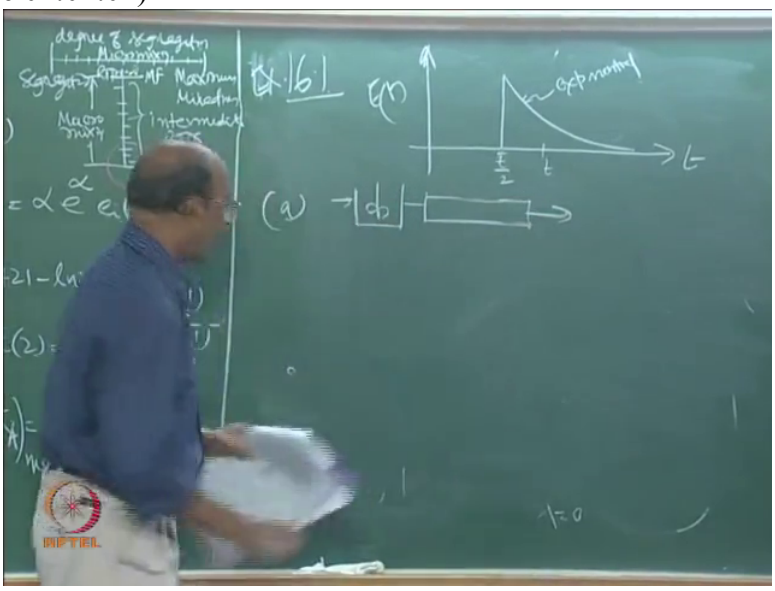

that is one; b is just reverse, Ok,

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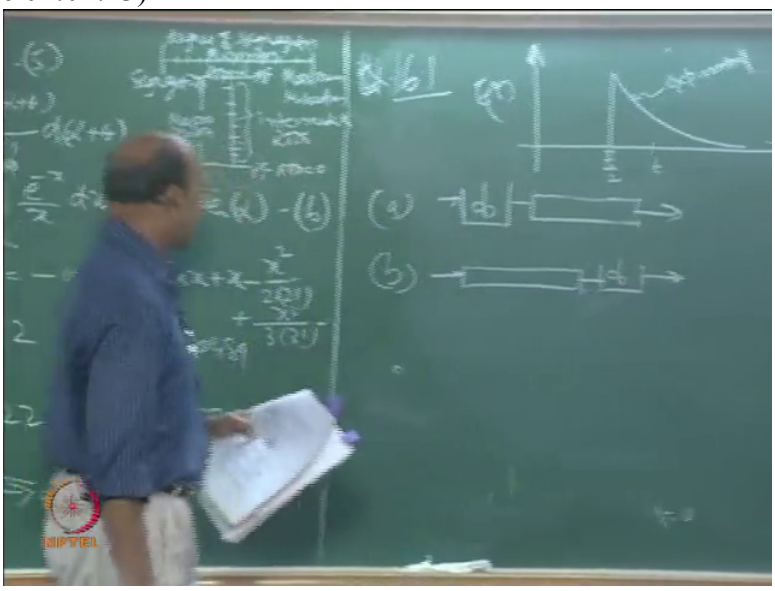

just reverse and the same thing here I have, Ok, you see R T D again cannot differentiate whether you have micro fluid or macro fluid. So this can be only for micro fluid. Ok.

Same two

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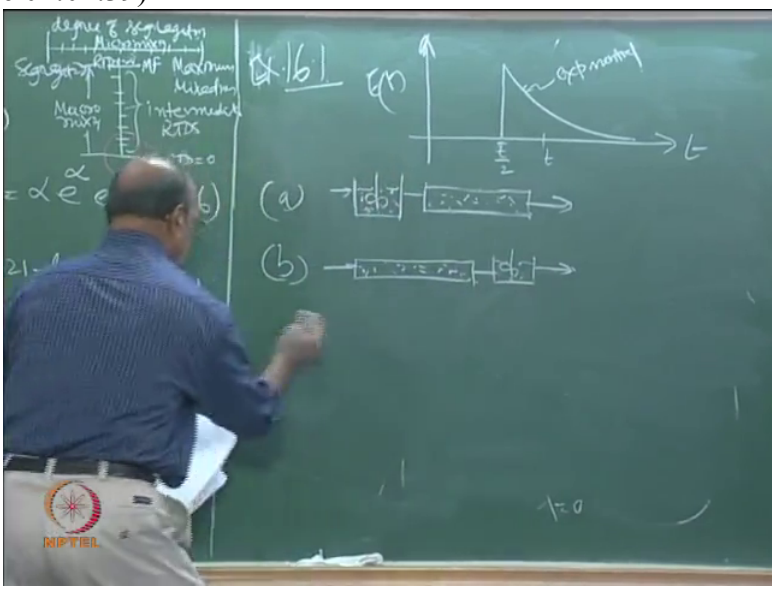

schemes I can also have for macro fluid. c is, d is...

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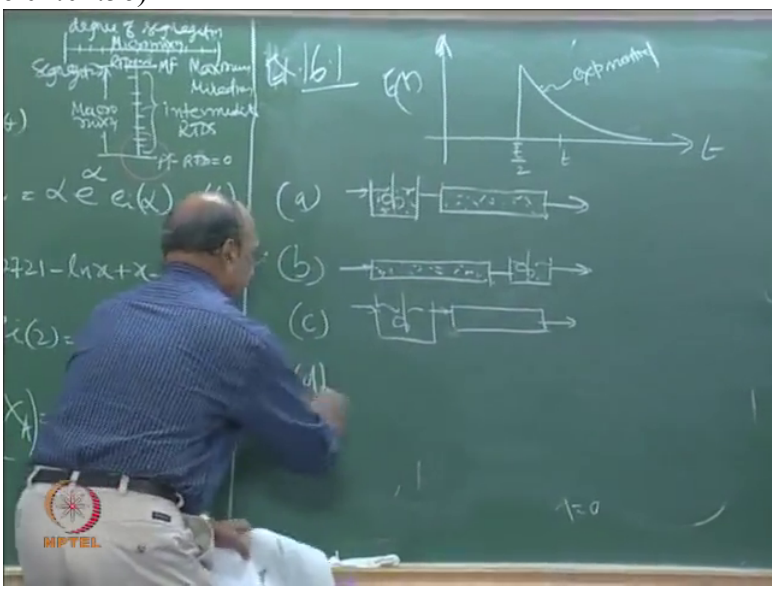

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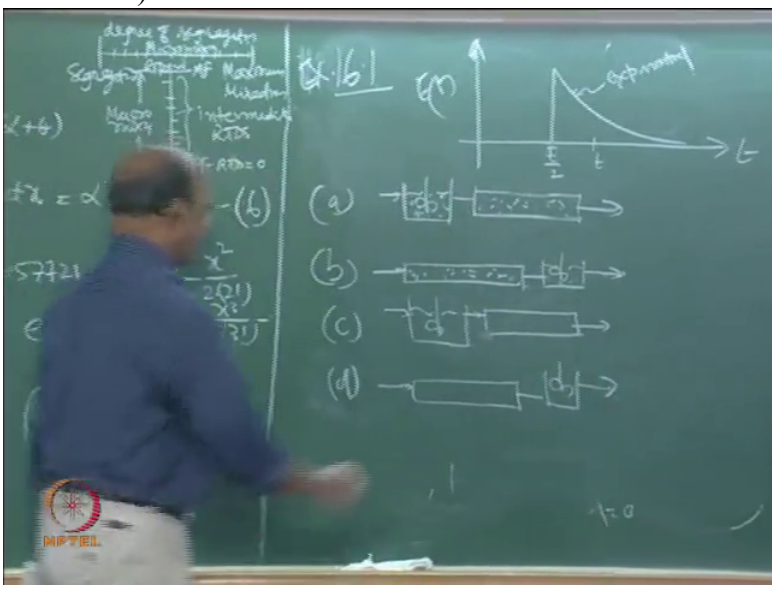

Right? Yeah, but here I have to show here packets. Ok. So that is the one. And is there any other possibility? Like exponential decay. Just now I had drawn earlier, e. I have, yeah; I have P F R, Ok, now I also have parallel P F Rs.

So like it goes, that is also possible, no? Right. Yeah, these are the possible schemes. Now out of all these, which one

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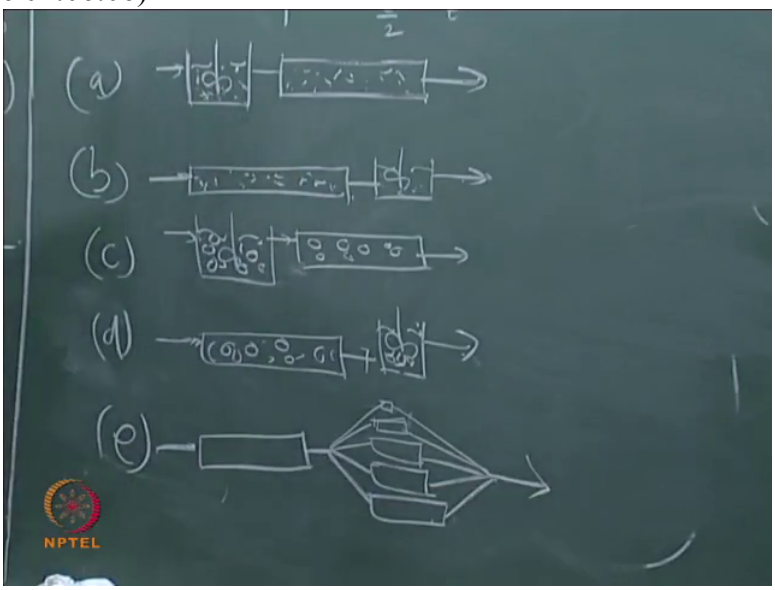

is the latest mixing, which one is the earliest mixing?

(Professor – student conversation starts)

Student: d is the latest mixing.

Professor: d is the latest mixing

Student: d

Professor: d, Ok, next one?

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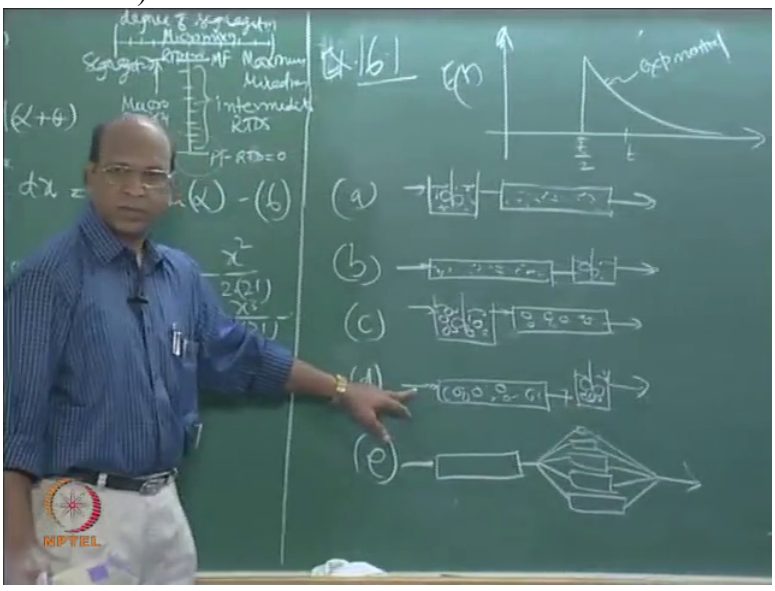

Student: c

Professor: That is all, only one? c also is

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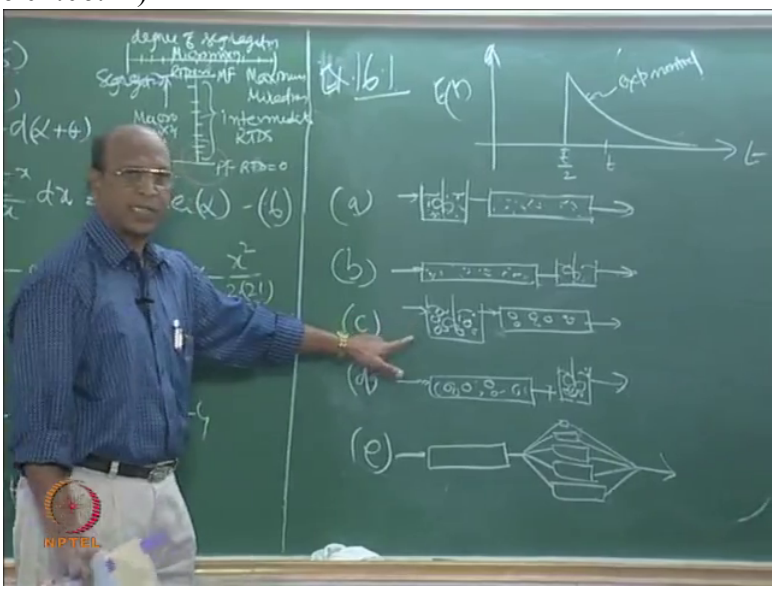

latest mixing.

Student: No, no

Student: b and d.

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Professor: Yes? Why do you say no, no? Some one is saying yes, yes... i will ask them why do you say yes, yes? See again you are forgetting definition.

Student: c is early mixing

Professor: By definition of micro,

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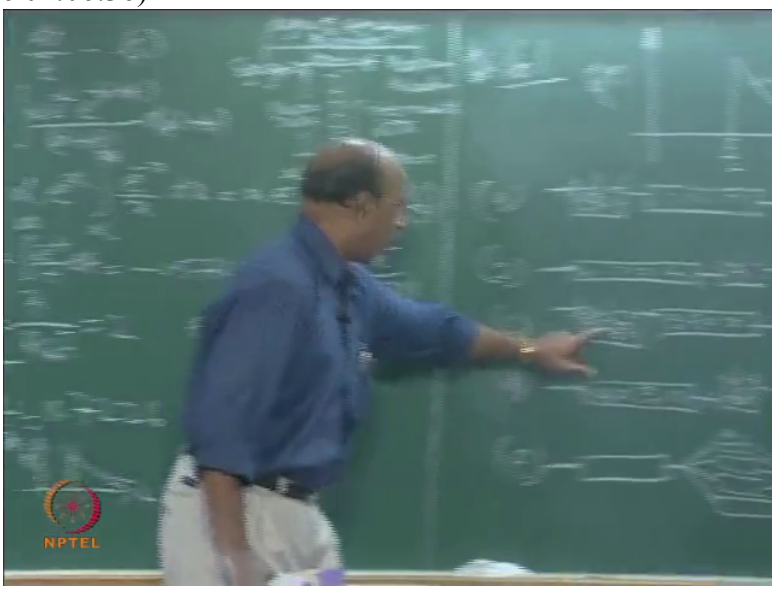

macro fluid, it can never

Student: mix

Professor: mix. Ok. So here I have macro fluid, here I have micro fluid.

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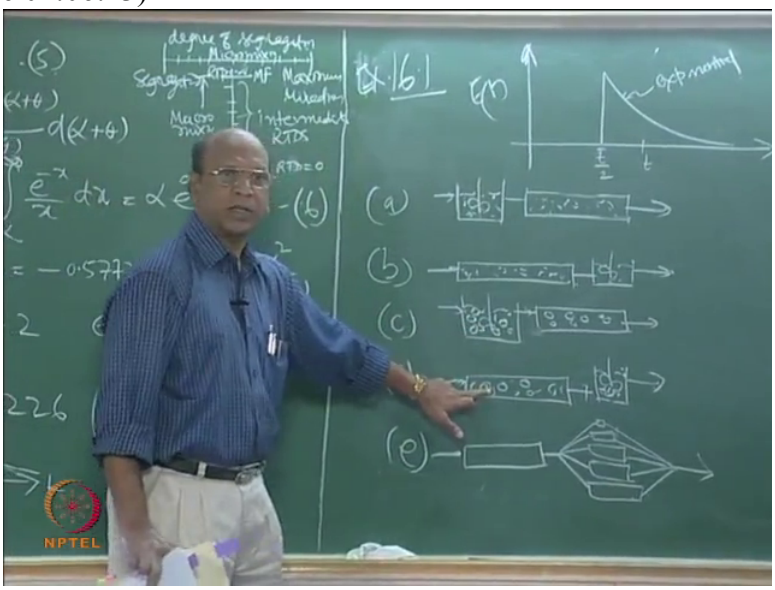

So both are late mixing or early mixing?

Student: Late

Professor: That is late mixing. And what about here?

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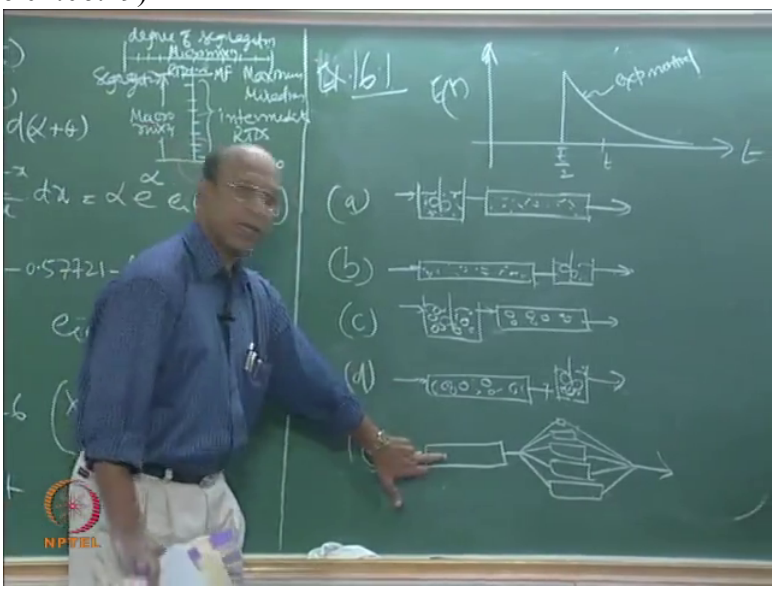

Student: Late

Professor: It is definitely late mixing.

Student: Late mixing.

Professor: We do not have to care. That is why we have not written separately for micro fluid, macro fluid. Either macro fluid or micro fluid both will give me

Student: Same

Professor: Exactly same thing. So that is why all these three, we have to use segregated model. What is segregated model?

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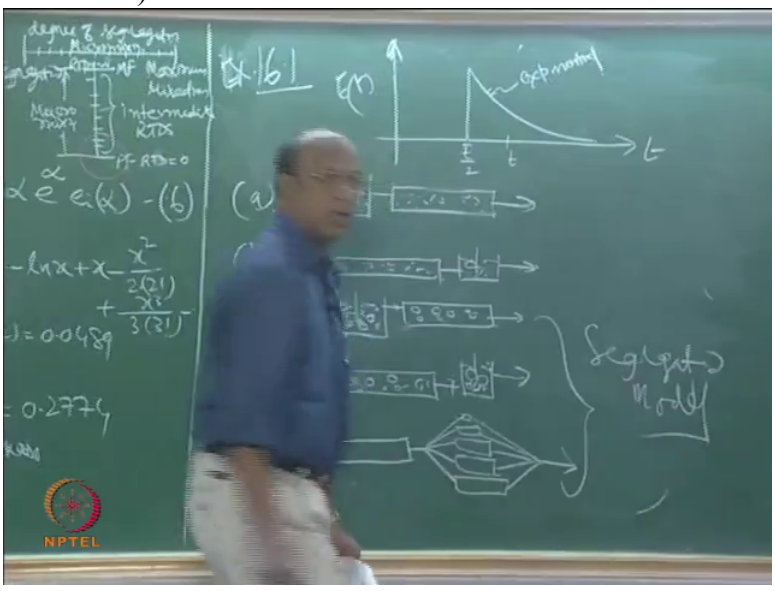

This equation

Student: Equation 1

Professor: This equation.

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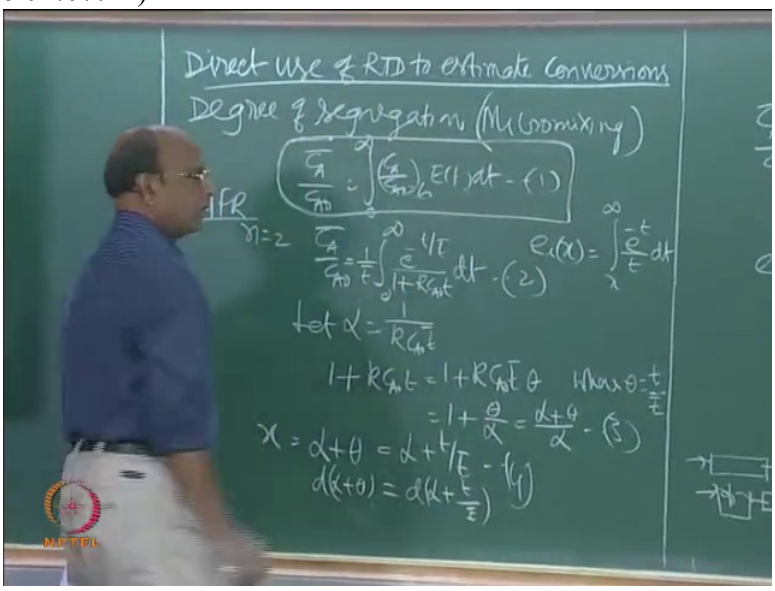

So if you know E t, and you have second order reaction, you can cal/calculate. He solved it beautifully and the first two a and b, here

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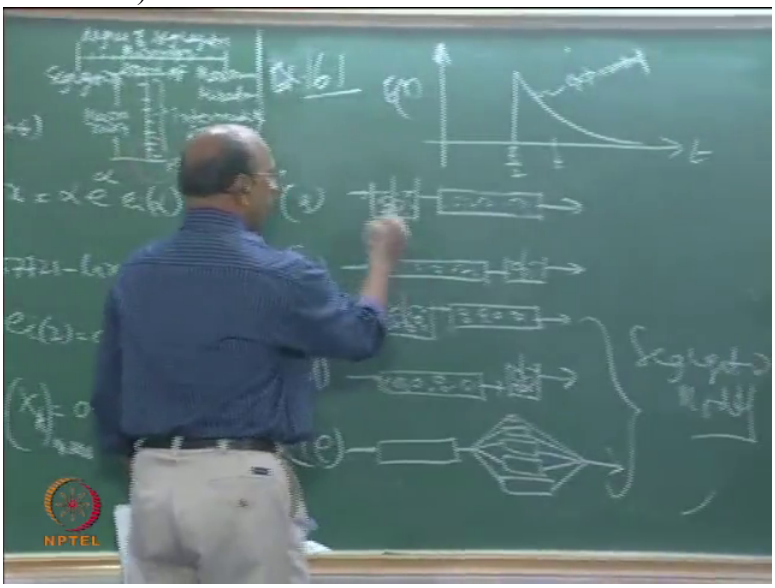

early mixing. Because it is micro fluid.

(Professor – student conversation ends)

But this is not equivalent to maximum mixedness. Please remember that.

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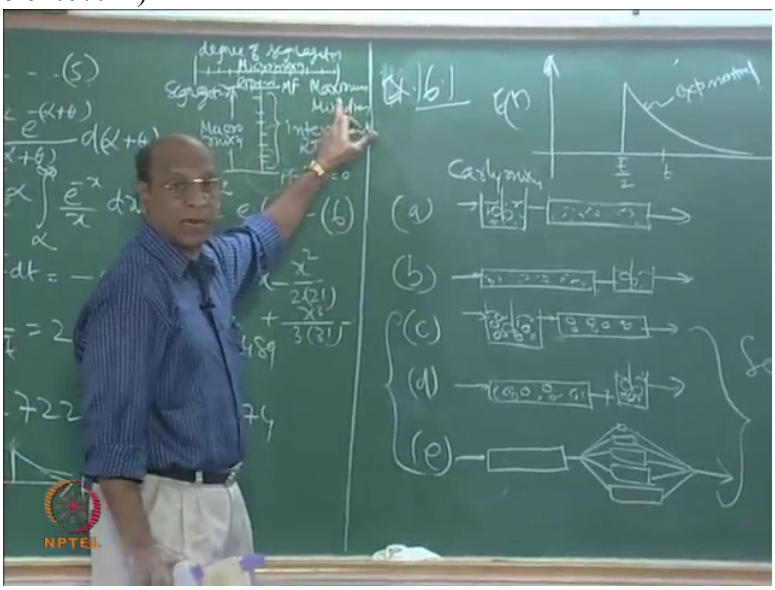

Maximum mixedness will be only for this one.

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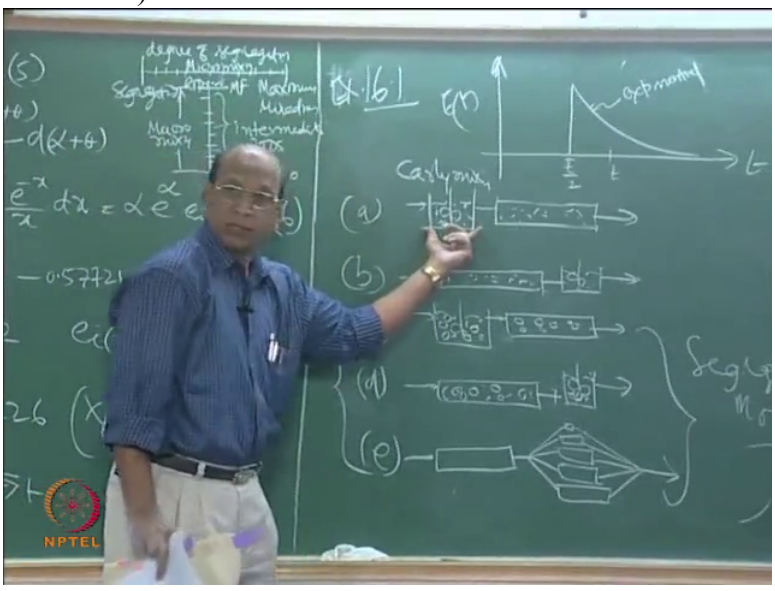

But you also have some other non-mixing component, correct no? You have a plug flow in between. So that is why this is early mixing and this is fairly late mixing.

Why we say fairly late mixing? Compared to what?

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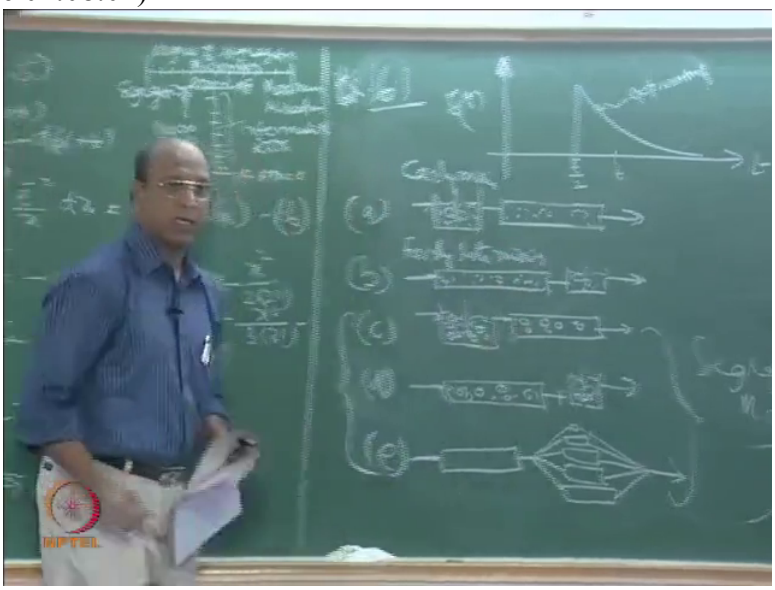

Yeah. Compared to these three. This is the latest mixing possible. This is late, but not as late as late as this, right? Because here I have plug flow, then I have mixed flow where mixing is taking place there at molecular level.

So this is the wonderful problem. Please go through that. And very nicely solved, simple and these two solutions already we have,

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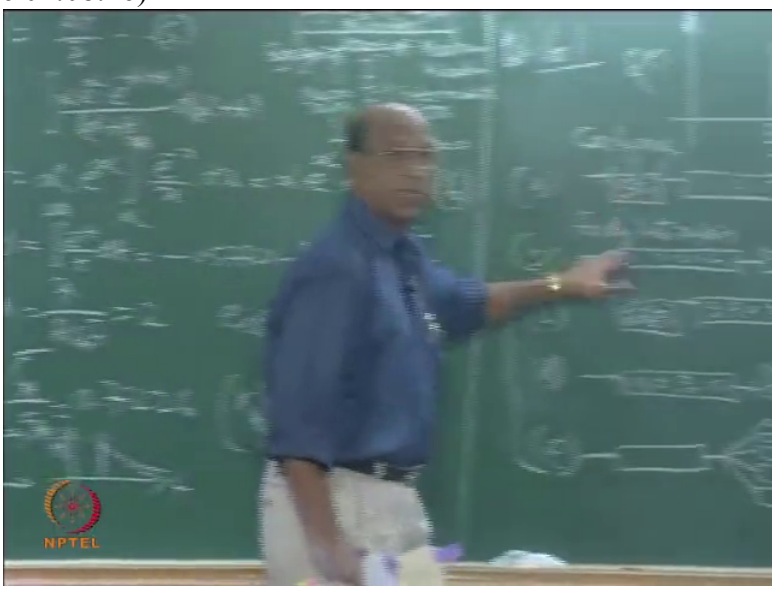

in the last class we have given x macro, x micro and all that. Ok. So this we have, yeah. So now we summarize. I requested Kannan that whether you can tolerate if I send these people 15-20 minutes late? He said no problem. Ok, Kannan class.

(Professor – student conversation starts)

Student: I have to go.

Professor: Whose class is yours?

Student: V G

Professor: Is it 0:58:53.3. Would you like to go? Not now?

Student: I have a class test now.

Professor: Then you have to go anyway. Then anyway. If you want you can leave now, or not now. You have test? After 5 minutes also you can go, no problem.

(Professor – student conversation ends)

Ok now let me tell the summary of what we have done. Micro mixing and macro mixing, Ok.

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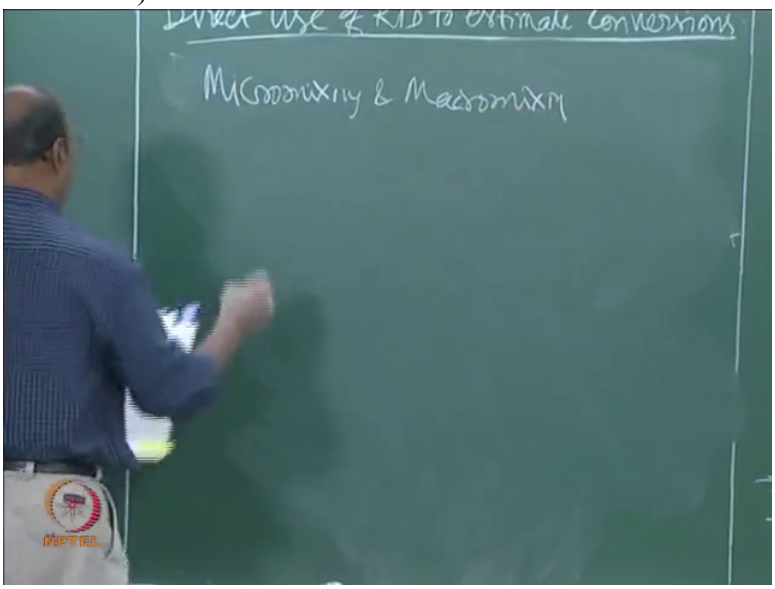

P F R, maximum mixedness, maximum mixedness or segregated flow, yeah so both will give me, Ok micro fluid plus macro fluid behaves, behaves same, Ok.

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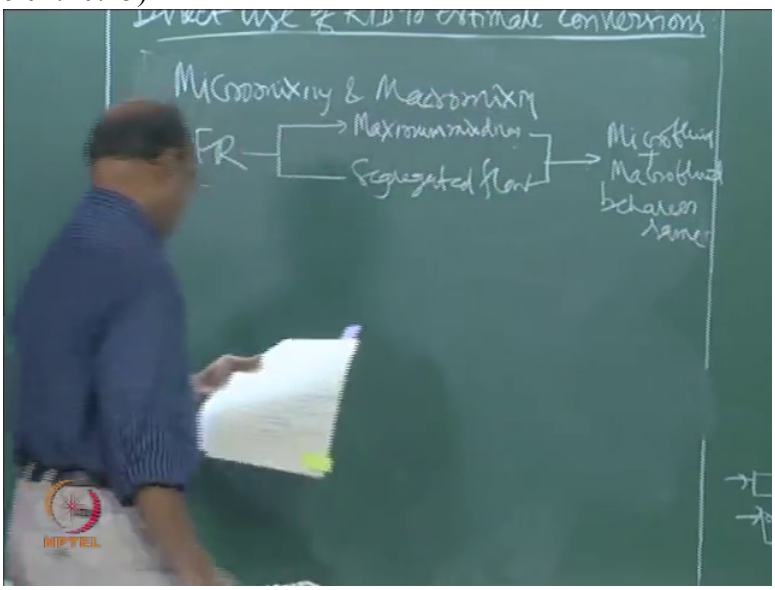

Then M F R, again we have maximum mixedness. Ok, that is mainly micro fluid. Yeah this is normal behavior, normal behavior. Normal behavior like your B Tech behavior. Ok. yeah, design equations derived in B Tech. Yeah, Ok.

Then we have, this one is segregated flow. Segregated flow macro fluid, this is one extreme, correct no. That is why you are assuming that, you know segregated fluid is one extreme, Ok, one extreme equations derived in M Tech. Ok,

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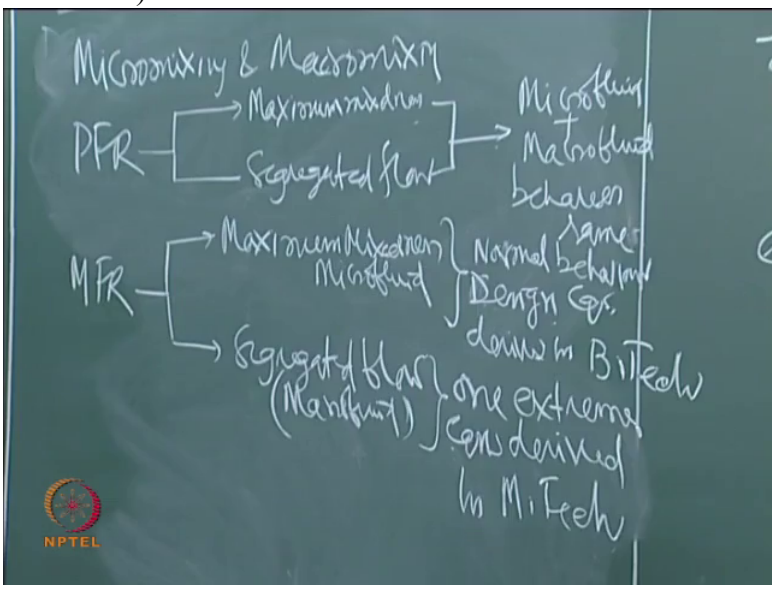

good.

Now, yeah this is M F R and in general segregated fluid if I have, segregated flow, you have a design expression, zero to infinity, C A by C A bar batch no, E t d t, so segregated flow, any R T D, any R T D, any R T D you can use that equation. Absolutely no problem. That is zero to infinity C A by, C A bar by C A naught equal to zero to infinity, C A by C A naught batch E t d t, Ok.

So here this is design equation derived in M Tech, M Tech at I I T M.

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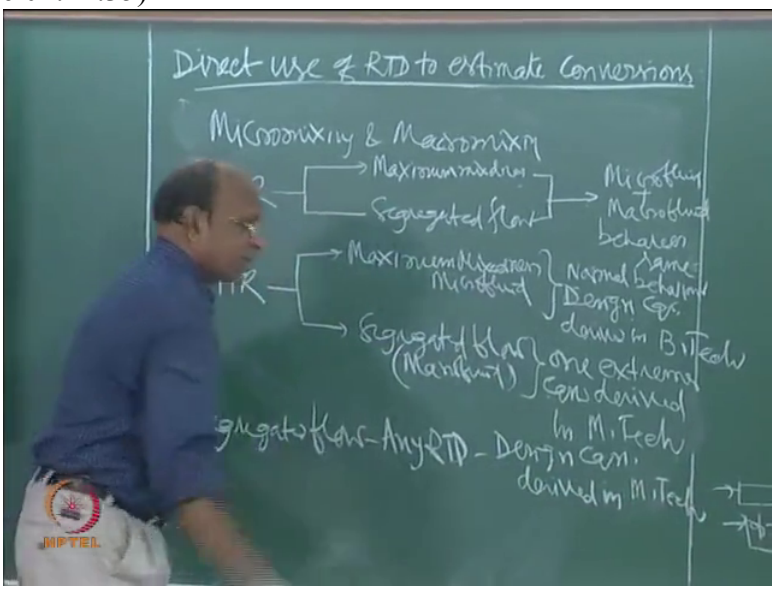

That is important. Because you may forget where you have done your M Tech, later. Possible, no? What Sivaramakrishna, you are very angry?

(Professor – student conversation starts)

Student: (laugh)

Professor: Sivaramakrishna?

Student: Not at all

Professor: Are you angry?

Student: I I T Delhi

Professor: Oh that is why? (laugh)

Student: (laugh)

Professor: Ok, good. Or of course M Tech I I T Delhi or I I T Madras for him. Ok.

(Professor – student conversation ends)

So now maximum mixedness. Maximum mixedness, any R T D, yeah, did you learn something, anything about this? Maximum mixedness, any R T D, Zwietering. Zwietering equation mentioned in M Tech I I T M, why M Tech, M S, M S P h D. So that is right, M Tech Che, Chemical Engineering. Oh, I think Arya also is there. Where is Arya? Oh she is there, Ok. Ok. Zwietering. So M Tech you have written, so M Tech.

Ok, Zwietering equation that is all,

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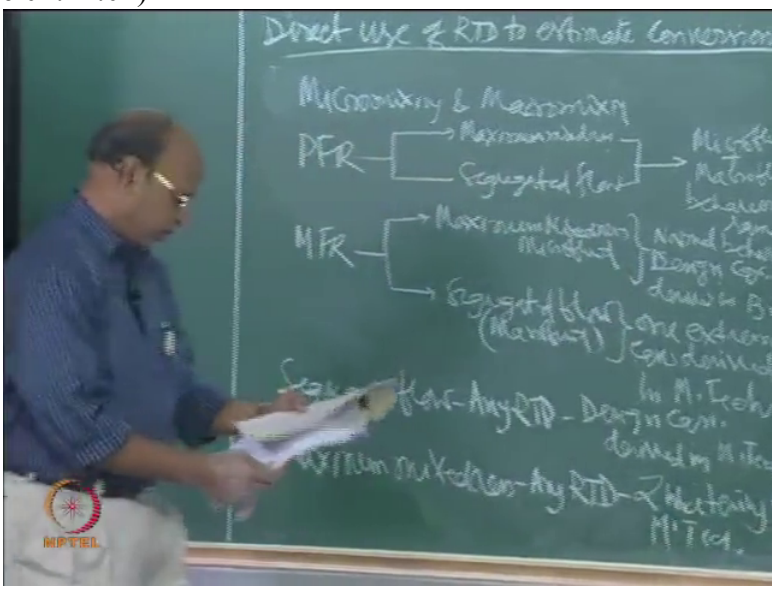

good. Yeah. See compared to Zwietering equation there is another technique which you have already done; you may not know that you have done that already. Ok. When you have micro fluids, there is another way of doing things. What is that? What is that, before this direct use of R T D, what is that you have done? What did we do there? What is the fluid we assumed?

(Professor – student conversation starts)

Student: Micro fluid

Professor: It was micro fluid. So if it is macro fluid, does not matter. You have a beautiful equation, zero to infinity, that one. Ok.

(Professor – student conversation ends)

If you have micro fluid you have both the extremes. P F R you know, M F R you know. In between R T D is difficult, but Oh Zwietering, Zwietering equation. I thought still it is there. Zwietering equation is valid.

But if you want to avoid Zwietering equation, go to axial dispersion method. Or go to tanks in series model. Or go to C S T R with dead space and bypass, and also number of tanks. You can have 3 tanks with dead space and bypass one after the other. So that will cover. But it is a two-step process.

But this is a direct use of R T D. Zwietering equation is direct use of R T D. That is why we call zero parameter model. There is no parameters in Zwietering equation where as if you go to dead space and bypass, you have 2 parameters. And if you take 3 tanks in series like that, then you will have another, another parameter. So n is a parameter. And the other two also, parameters. Ok, so that is why.

So, and the equations which we can write now, I think I should have listened to Rahul because he was telling Sir; we will take Xerox and give. But I thought you know let me write here, Ok. Yeah, equations for, for Kannan's people, I think students, do not worry. I think he said he accepted. Last night I called him.

Equations for single fluid,

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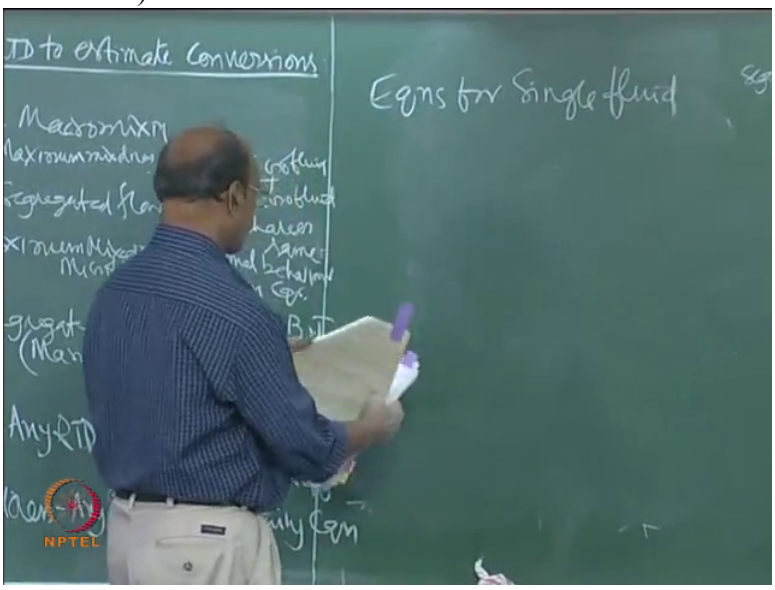

yeah, Ok 1. For micro fluid, please take this, for micro fluid, P F or M F,

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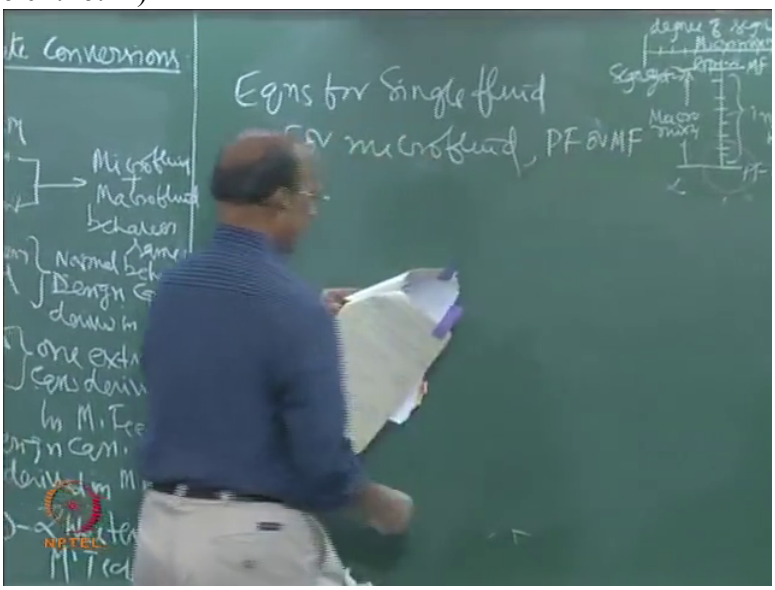

any kinetics. Or otherwise I think I will distribute this one to, later, this is only summary again. I think I will distribute. Tomorrow also I can distribute. Ok, I think we will take today. Tomorrow, design class also I can distribute. It is only just summary. Because I have other things to do, so that is why. Ok. Ok you can give this one? This one, this one only.

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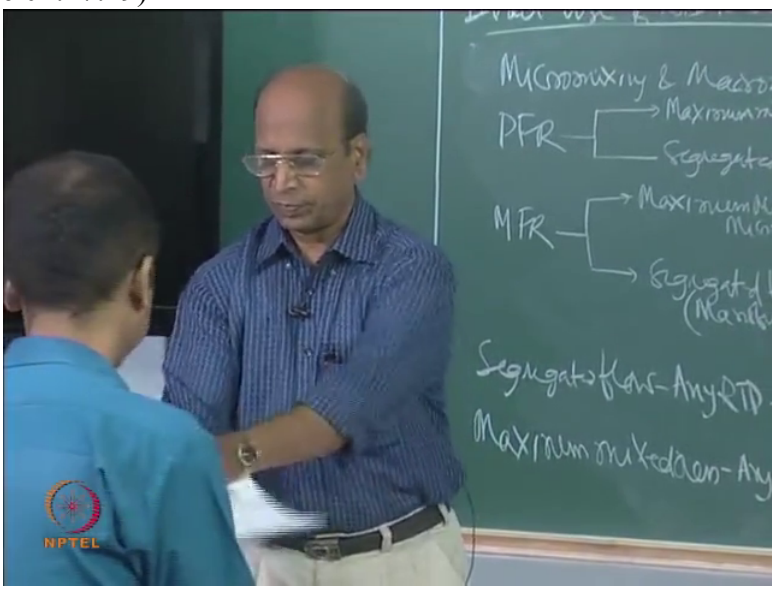

Some cartoons, yeah and also now I think we can give sweets, no?

Oh this I think I have to explain. This I have to explain. And afterwards we...This is 2 pages. What happened?

(Professor – student conversation starts)

Student: (Applause)

Professor: Clapping afterwards (laugh)

(Professor – student conversation ends)

Ok, you got this now or what? Ok. Everyone got this? Yeah, now you see. We will explain. The first one, stage 1, Ok, stage 1 is input, kinetics, ideal contacting because you know only M F R and C S T R, sorry P F R and C S T R, Ok and you see this guy is very happy, very bright eyes and then saying, ha I know reactor design fully. But it did not work, X i is different.

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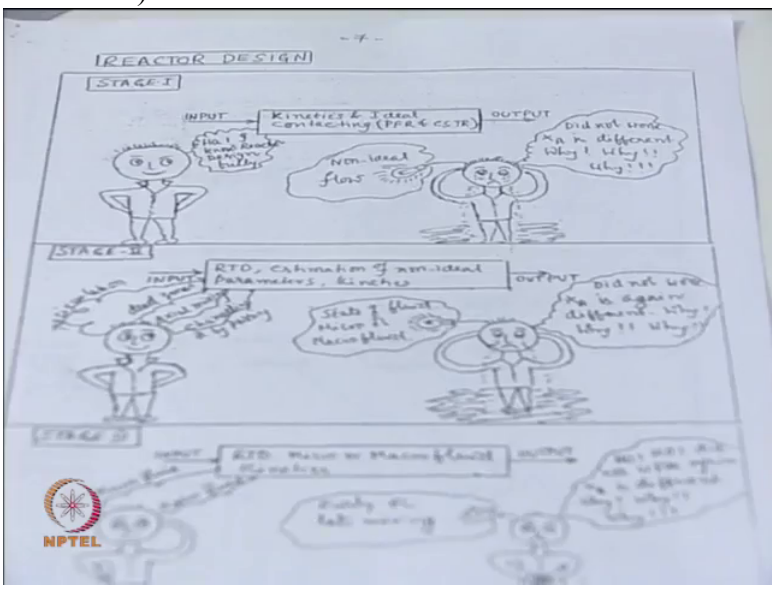

Now started weeping, why, why, why? And you see lot of tears and bottom also there are lot of tears there. Ok. So that is one. Then you can see, when he thought, ha I know reactor design fully. Collar up and all is there.

(Professor – student conversation starts)

Student: (laugh)

Professor: Did you notice that?

Student: (laugh)

Professor: Ok, collar also up there.

Student: (laugh)

Professor: Yeah, that is the one.

(Professor – student conversation ends)

And next one you see, afterwards again he thought that non-ideal parameters, you know, a bulb came and then he thought that non-ideal parameters is one, you know, these parameter may affect the conversion. And he introduced them, he introduced them. Recirculation, dead zones, axial mixing, channeling, bypass and all that.

Because he was confident second time also, again collar up there.

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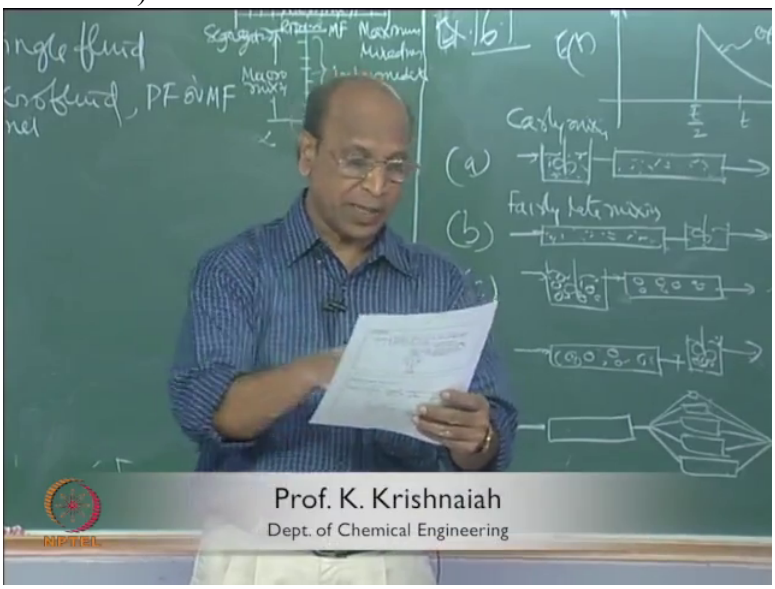

Because you know he thought that it will work. So then again, second time also he did not get same conversion. Then you know, did not work, X A again different, why, why he started weeping. Lot of water and all that.

Then again bulb came. Then he thought that he has to take into account macro fluid and micro fluid. That he has taken. Then I think he is Ok in the third stage because the collar gone by that time. Because

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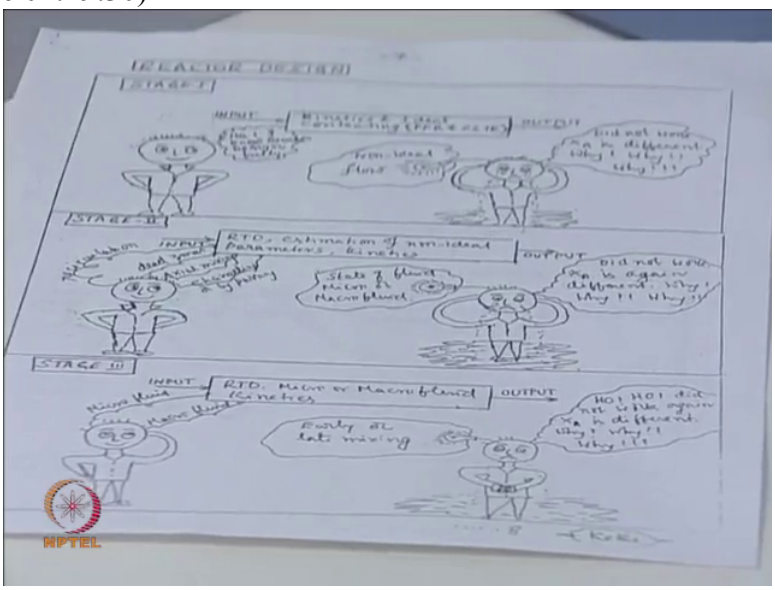

all pride has gone (laugh). Because thought that there is no use of being very proud

And then started, Ok introduced macro fluid and micro fluid and that also did not work

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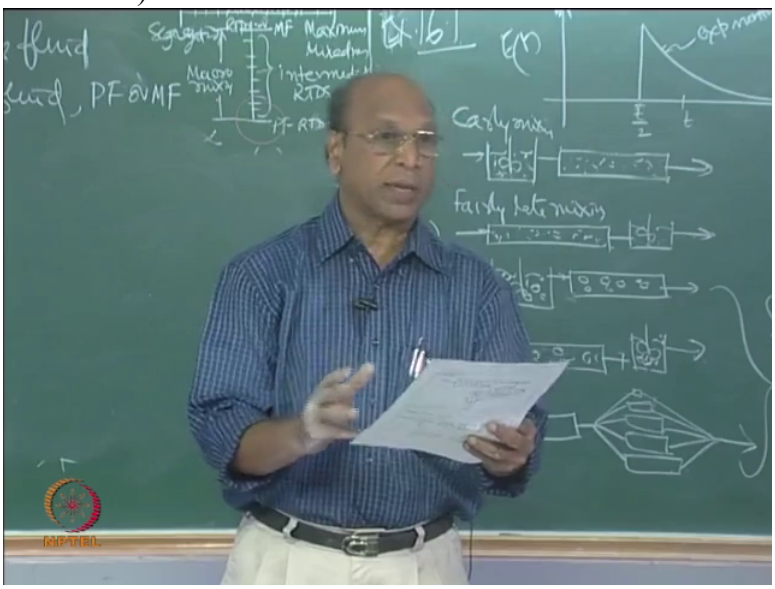

because he did not know there is early mixing and late mixing. Ok. So finally in the last one, he has introduced kinetics, R T D, micro fluid, macro fluid, late mixing, early mixing, everything. Then his eyes also got straight. Now it is straight looking. You know no. Happy and all that.

That also

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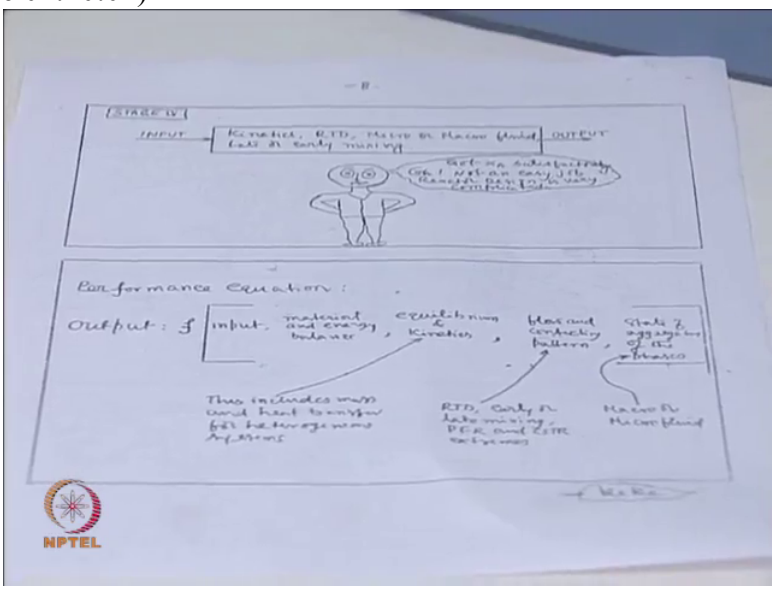

you see, from the beginning to the end, by the time he came to the fourth stage, no hair, only solid head, that is all. (laugh) So this cartoon will definitely tell you, you know, so beautiful things now

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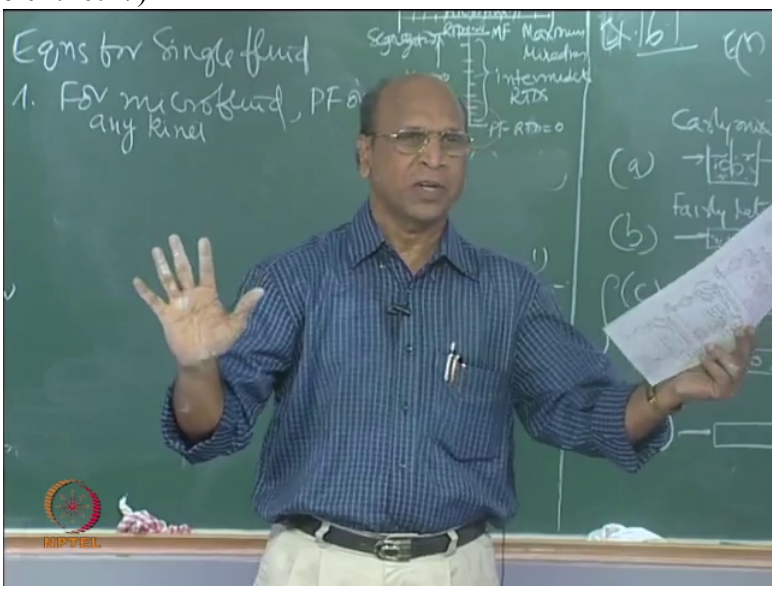

and I thought, just keep it with you and this is very nice, so that you know, you will have some, you won't forget if you look at a cartoon, so what are the so important things, that one.