Chemical Reaction Engineering 1 (Homogeneous Reactors)
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Department of Chemical Engineering
Indian Institute of Technology Madras
Lecture No 29
Recycle Reactors

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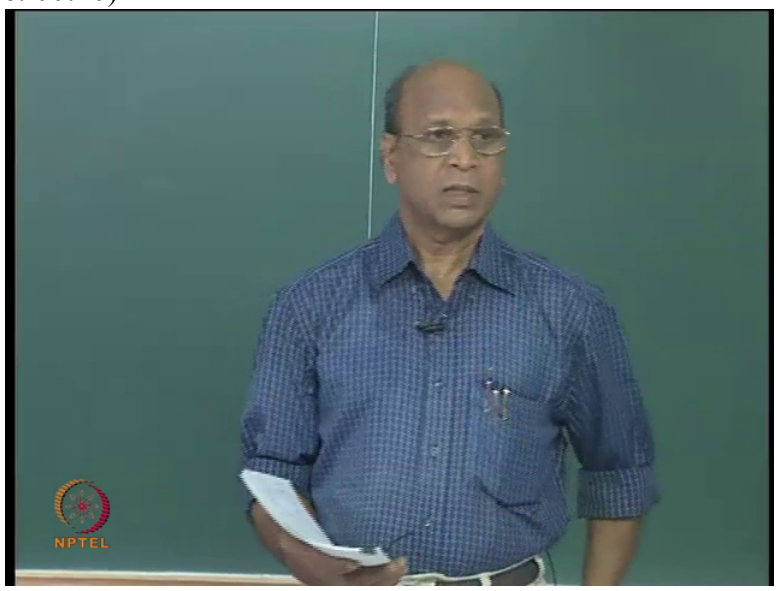

So do you remember anything about recycle reactors now? The expression which we have derived, of course there was lot of discussion and then also I think I could clear as much as possible the doubts. You still have some doubts? Or I know you would not at all put your brain at all on this.

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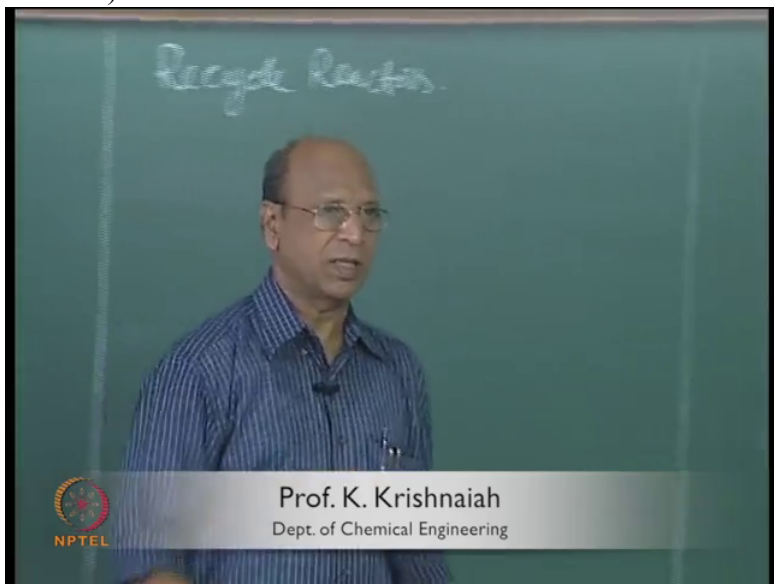

Because is only till fifth chapter no, single reactors. So multiple reactors, even though this is a single reactor, Ok.

So the expression what we got finally was that V by F A naught is equal to R plus 1, integral X A 1 equal to R by R plus 1 X A f. This is X A f, d X A by minus r A. So this is the derivation, design expression

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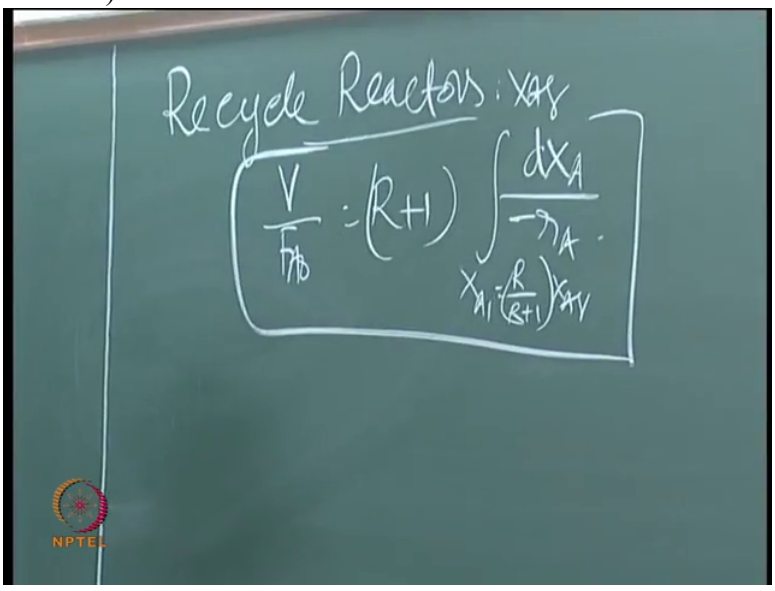

for recycle reactor. Ok, good.

And you should start doing that, you know. Those people I do not know whether all of you have done well in the examination and in spite of solving problems if you have not still got the correct answers or not able to do all the problems means still it requires more training, more practice. Ok.

So this mental solving again I am repeating, please do not do that. Mental solving means no, looking at the problem, reading so what is given in the problem, only volume so you try to find out whether conversion is given, F A naught is given, rate is given, Oh everything is given. I can calculate.

So you cannot say that you know you have solved that problem. Unless you put on the paper definitely you cannot solve a problem. Particularly in engineering, that is true.

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Because specific answers, specific type of you know the procedures all that is also required.

This is a training for you I say, to go to industry and also solve their problems. It is not just to get the degree. Or just to get the, you know, every time an examination passed. Not that. Ultimate aim is that this training goes to industry where you should be able to design a reactor or distillation column or

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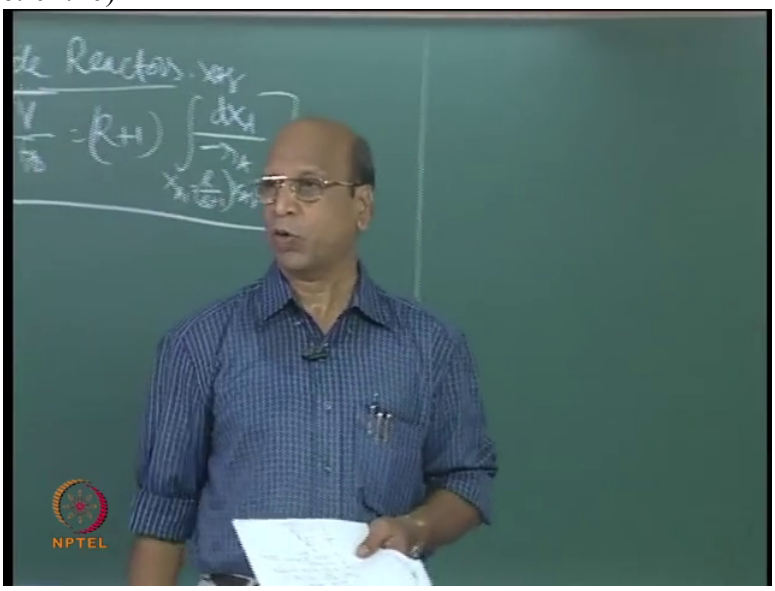

whatever equipment without any mistakes, Ok.

So that is why even this one, still you will have lots of doubts, right. And I am sure you would have never discussed about this with yourself, Ok. So again you know you will postpone all this thing till next examination. That is the problem.

(Professor – student conversation starts)

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Student: We use recycling basically because mixing is required between P F R and M F R

Professor: Yes

Student: But when I look at it, it looks slightly like P F R to me. Why do we say...?

Professor: Where is P F R?

Student: In the example, we used a P F R.

Professor: Yeah we are using P F R

Student: And then we recycle it.

Professor: Yes, recycle it.

Student: There is no axial mixing 0:02:56.8

Professor: How? Yes, there is no axial mixing, ideal P F R only.

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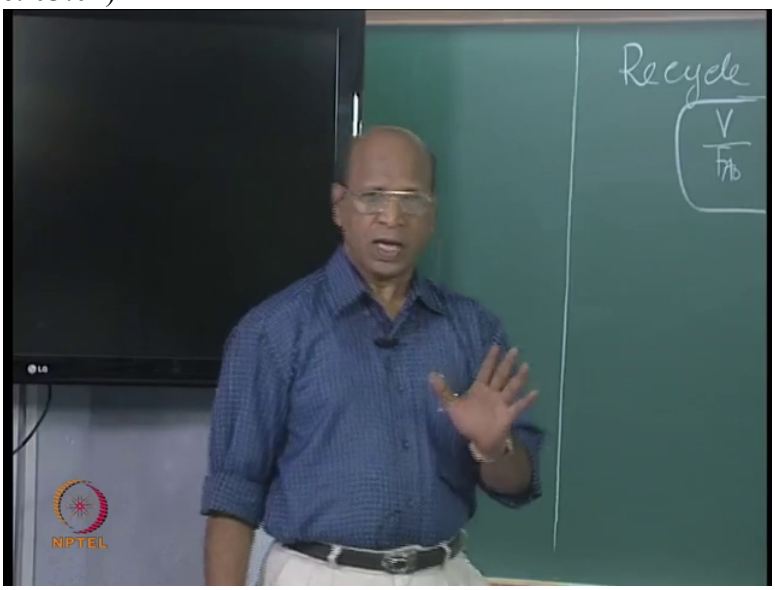

Ideal P F R but why do you say it is P F R?

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Student: 0:03:06.2

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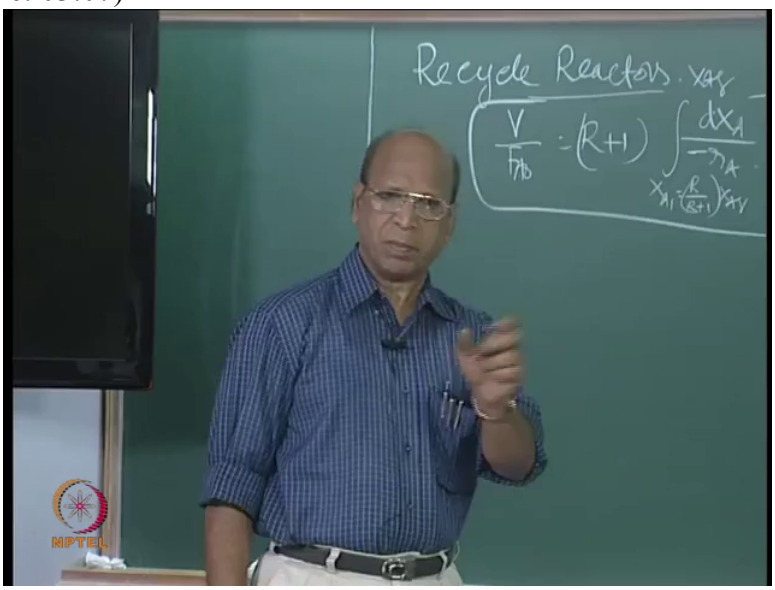

Professor: It is a P F R but with recycle means what is the concentration that is entering? Where is this lower limit for P F R?

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Student: 0:03:15.8

Professor: Where was this equation in the

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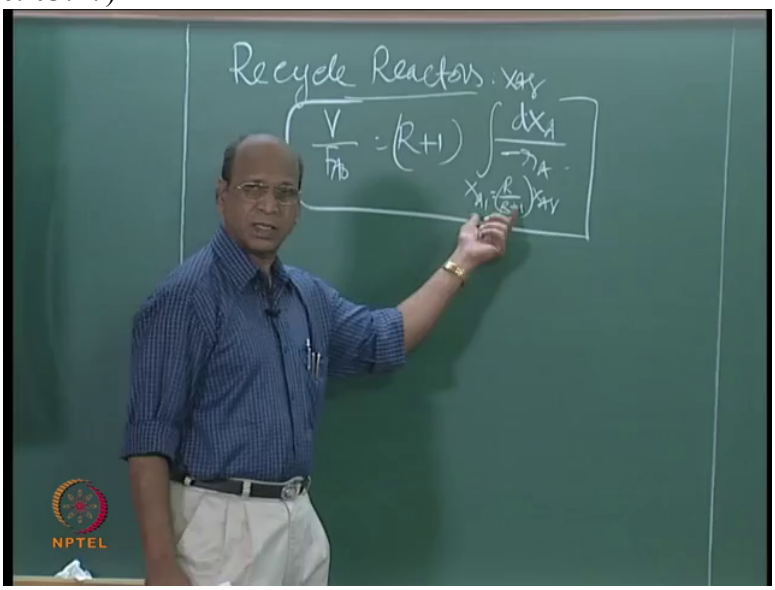

P F R?

Student: It was not there

Professor: Why?

Student: Because

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that is part of recycle.

Professor: That is the difference. That is why it is recycle reactor. How can you say it is P F R?

Student: No, but recycle that was there but mixing is required...

Professor: Yeah this is what is mixing.

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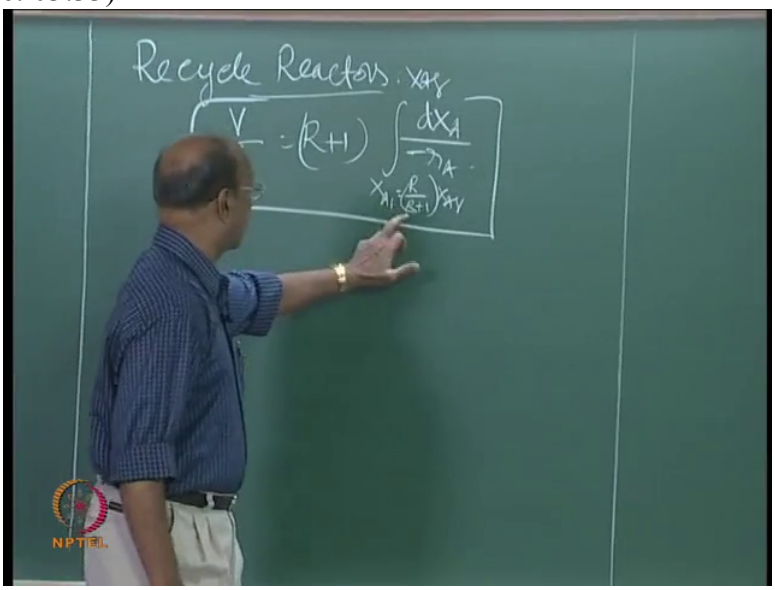

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Student: That is right. I want to say that only, mixing.

Professor: It is you take the product inside and then, no all the all products again you are recycling back and then you are putting

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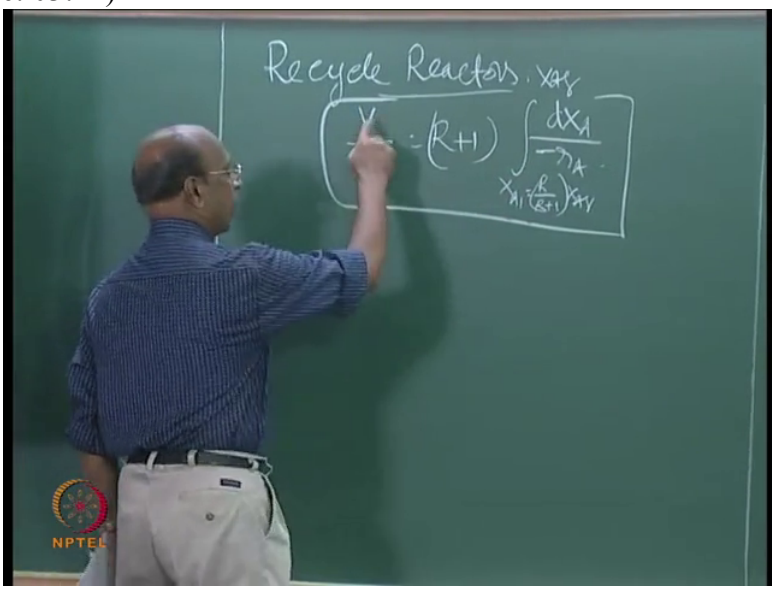

along with the fresh feed. It is not outside, no. Once the fresh feed comes then only it joins. Ok. So these two are mixing and then entering. So that means when the stream is entering the plug flow reactor, you have products as well as reactants. Is it there in the other thing, in the plug flow? It is not there. Ok.

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(Professor – student conversation ends)

So that is why and intermediate mixing will come because depending on

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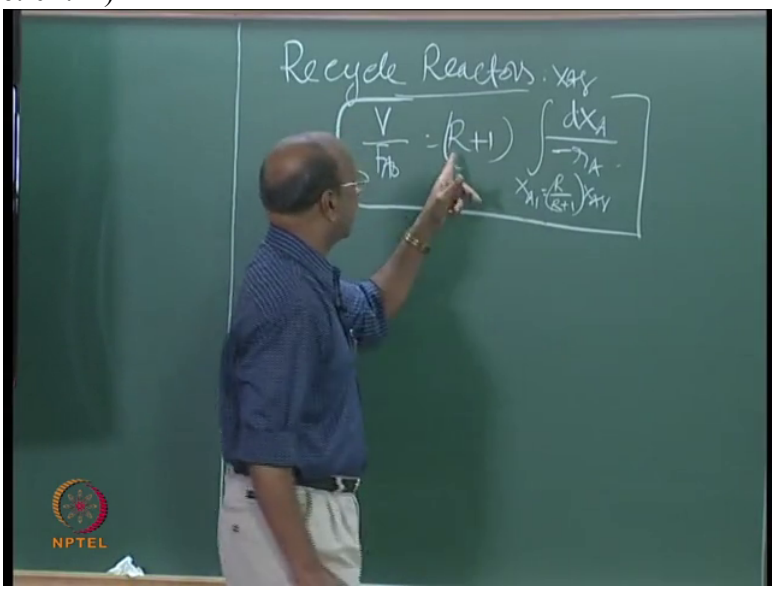

R. Ok, yeah. And I also told you. Again I unless give in the examination none of you may not care about this. I can give some derivation as a surprise test also that show me that as R tends to infinity it is a mixed flow reactor, and R tends to zero, it is a plug flow reactor. Ok. That is the beautiful problem. You have to use wonderful concept otherwise you cannot solve that equation.

So that is why you can definitely have the mixing between C S T R and M F R. When R equal to infinity we can show that this is equal to exactly V by F A naught equal to X A by minus r A. You will get that, beautifully you will get. And R equal to zero we know clearly I think the straightforward you can get that integral expression. So that is why happily one can get. And anywhere in-between, depending on the R.

Ok that is why it is a plug flow element but I am now trying to take some of the products and put it there in the beginning. Then the rate that is entering is not zero. In the normal plug flow reactor, the rate that is entering is zero. I mean there is nothing.

So mixing comes, that means this rate should have happened because already some kind of reaction there, right? Yeah. So that is the reason. That is the reason why it is called the recycle reactor even though as you said correctly it is deal P F R element with products mixing there.

And when you add products, then temperatures will not be there that means you will control the rate; rate of reaction will not be very high. So temperature control is important means you

can use that and when you come to multiple reactions I will show you when you are also able to use recycle reactor.

Ok, under some conditions you need intermediate mixing. It is not always somewhere between the extremes.

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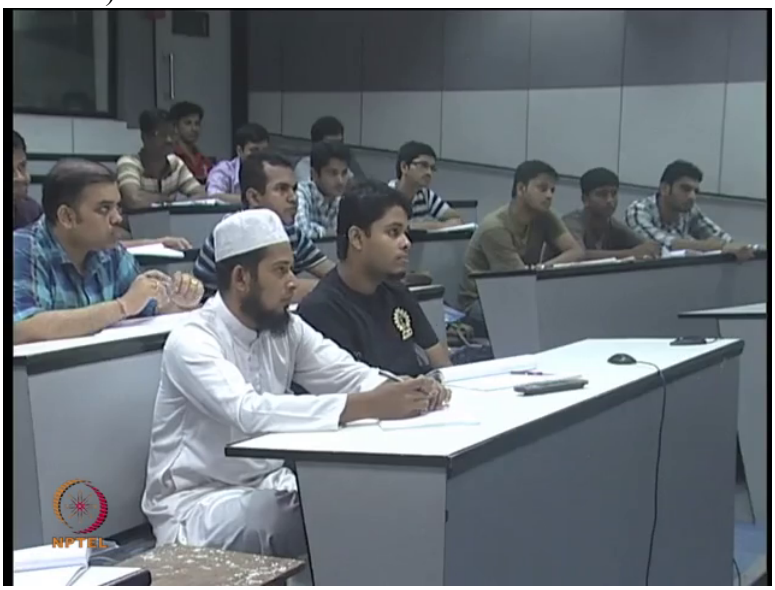

It is not always the extremes. Somewhere in between also you have to use it. Particularly for multiple reactions. So that also I will just show that one to you. Ok.

So now this one

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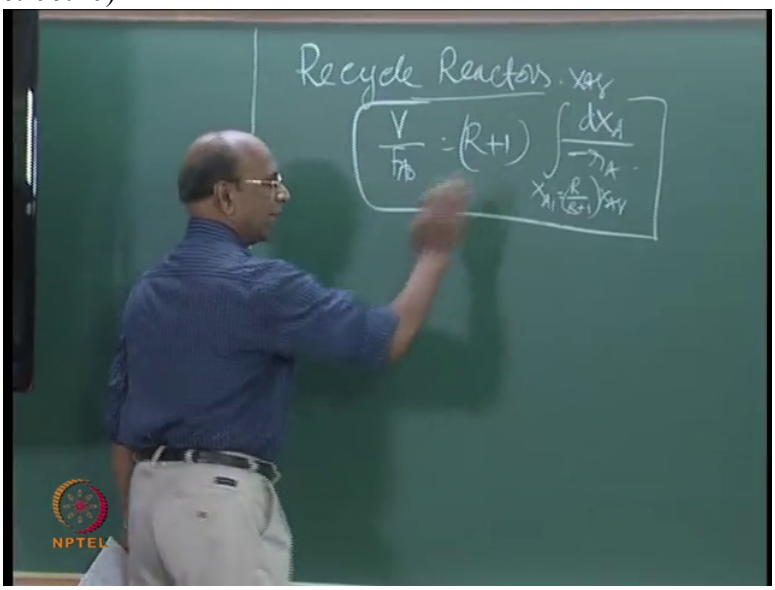

graphically how do we plot this? I think it is not easy for you to imagine this but let me try and with little bit of clarity in the mind, it is not difficult also to understand this. Normally we are plotting, because in this element you see.

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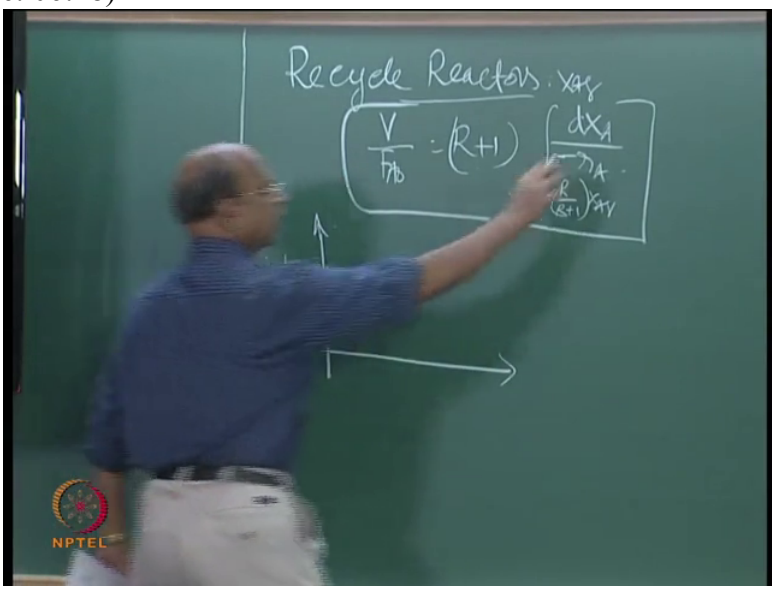

Here in the integration you have only 1 by minus r A versus X A, so that one, Ok. So normal reactions you may say something like this.

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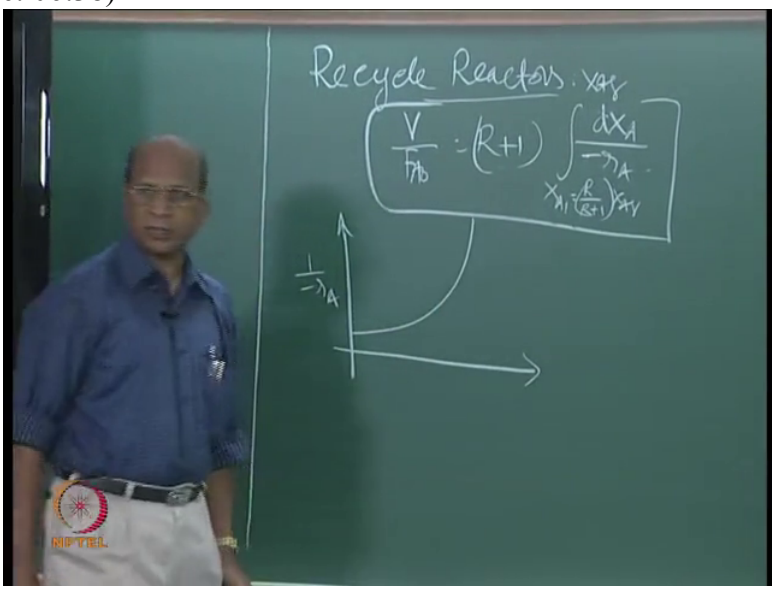

You know rate, 1 by minus r A versus X A, then I will have here, this is my final conversion X A f, yeah

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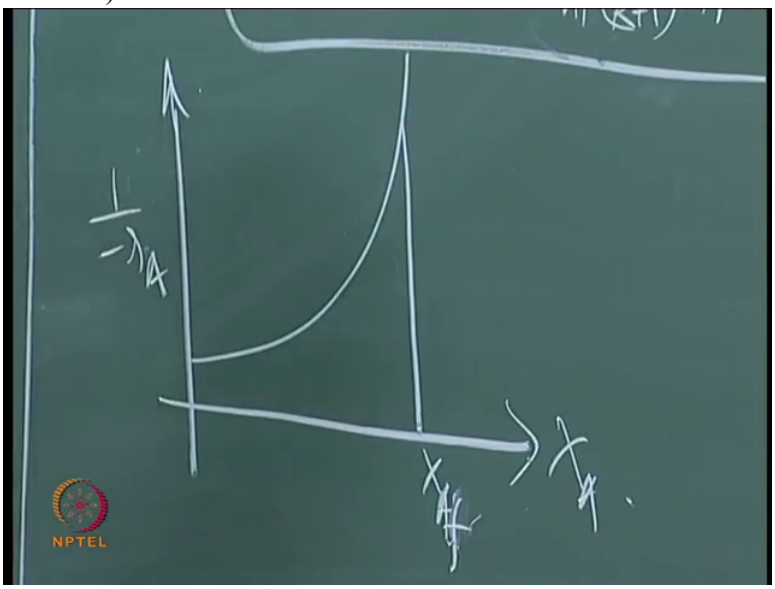

so now what area I have to take here?

If it is only R equal to zero what is the area you take? Area under the curve, Ok, area under the curve. If I have V by F A naught

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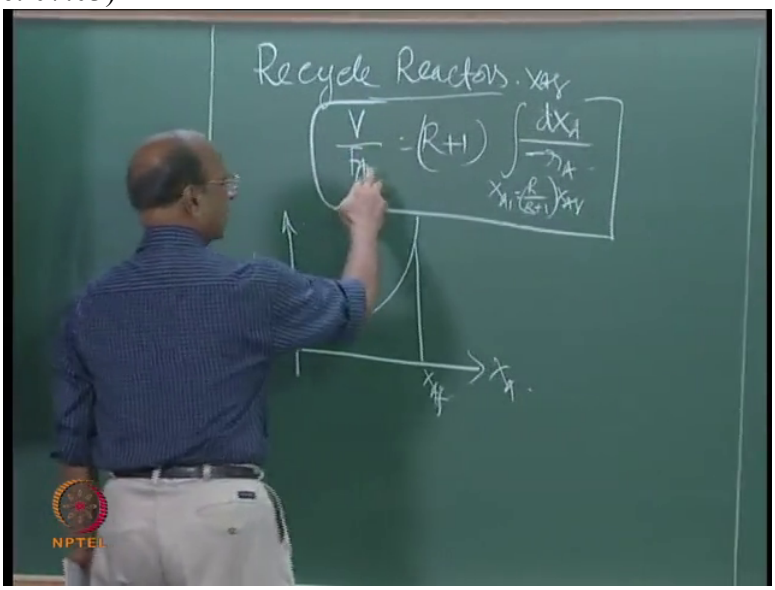

equal to X A by

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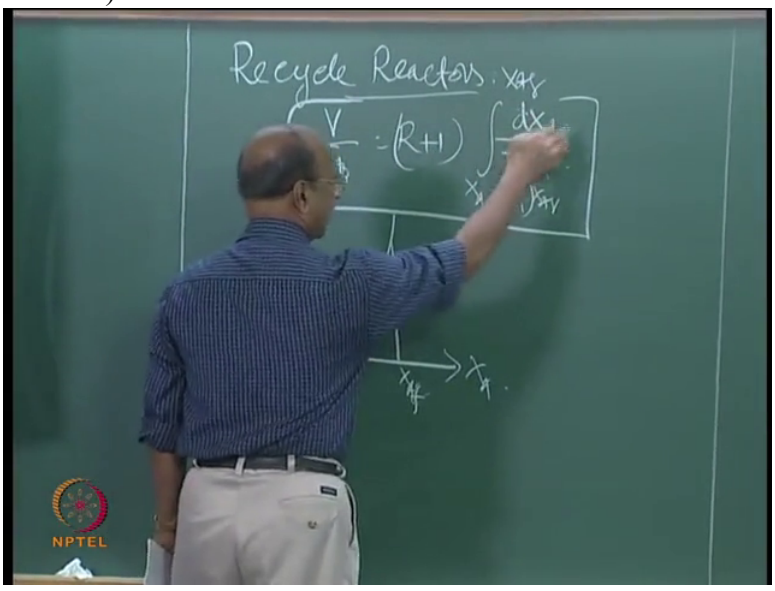

minus r A, that is for ideal plug flow, then I take this entire area, Ok.

But now it is not that. It is somewhere in between those two, correct no? The two extremes we can easily imagine because already you have done but this is mixing, you know this recycle reactor creates

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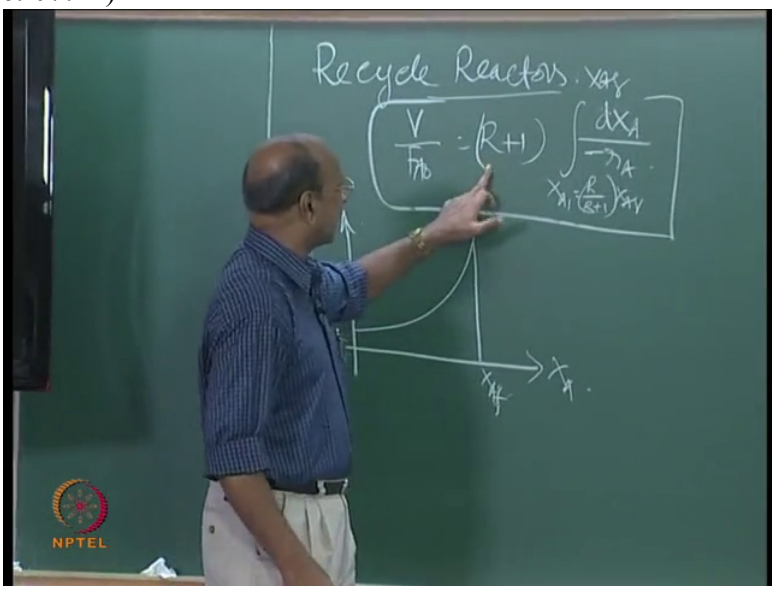

some kind of the products and the reactants mixing together and then entering.

So definitely you will have a value less than mixed flow and of course greater than plug flow because there is this element coming. Ok, this, this and then the lower limit coming. So now let me identify this one as only this part.

That means I can split this equation into two, R into this integral

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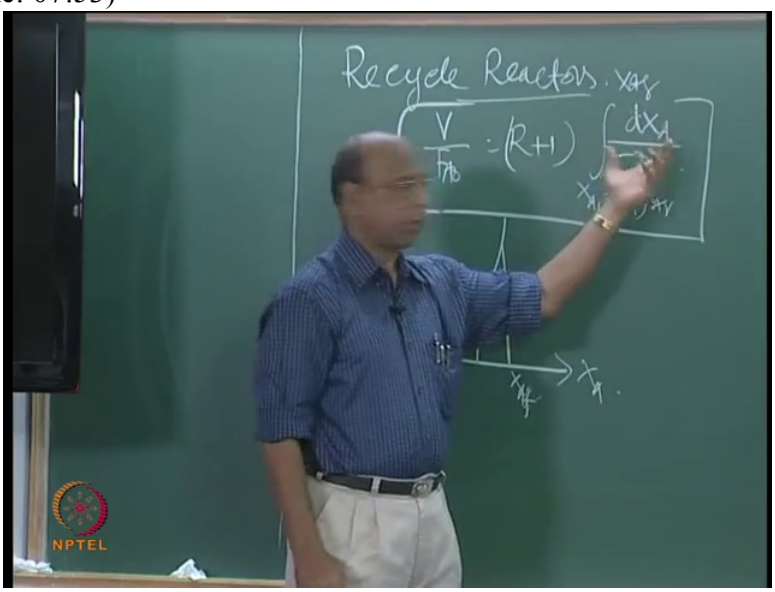

plus 1 into this one. So that 1 is here, this is X A 1.

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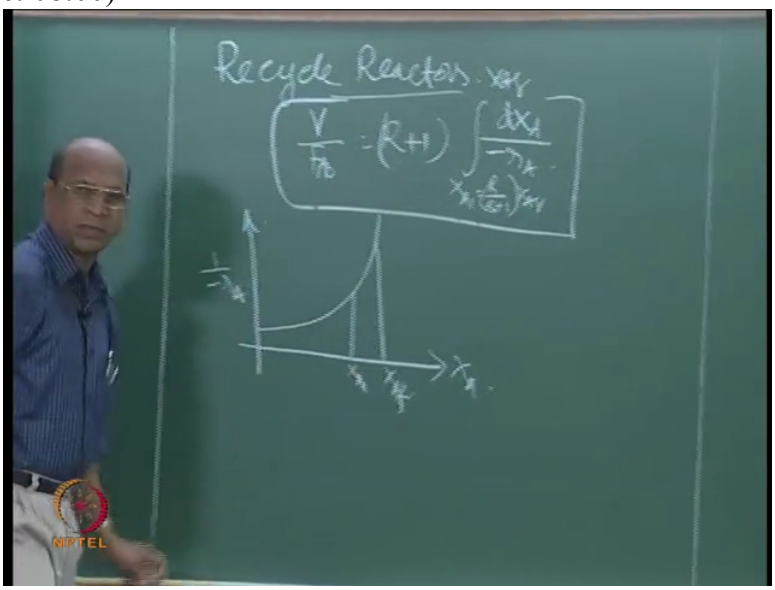

Ok, so because this is 1 into simple this one, this is lower limit so this is the area which I have

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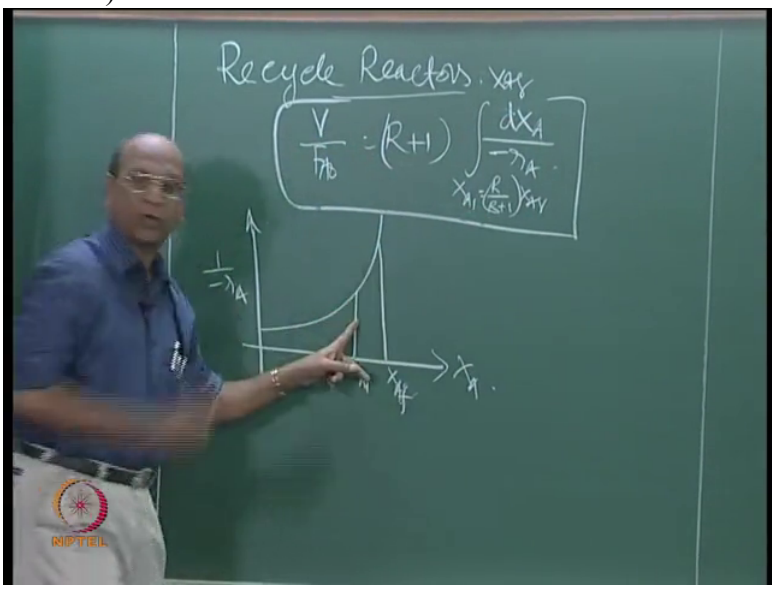

to take. That is understood no?

So this V by F A naught, I will, if I

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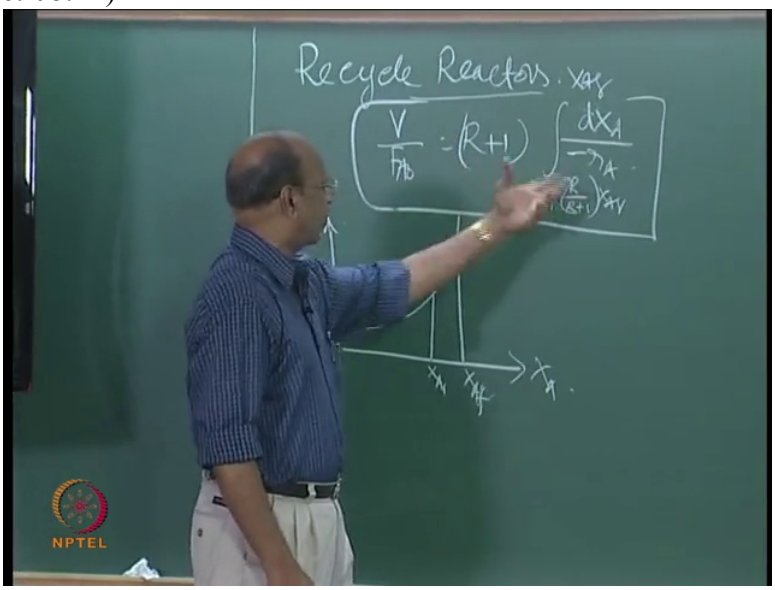

split this equation as R into this plus 1 into this, Ok let me write, R into this integral, plus 1 into this integral. Ok. This is Ok, so this is what first I plotted.

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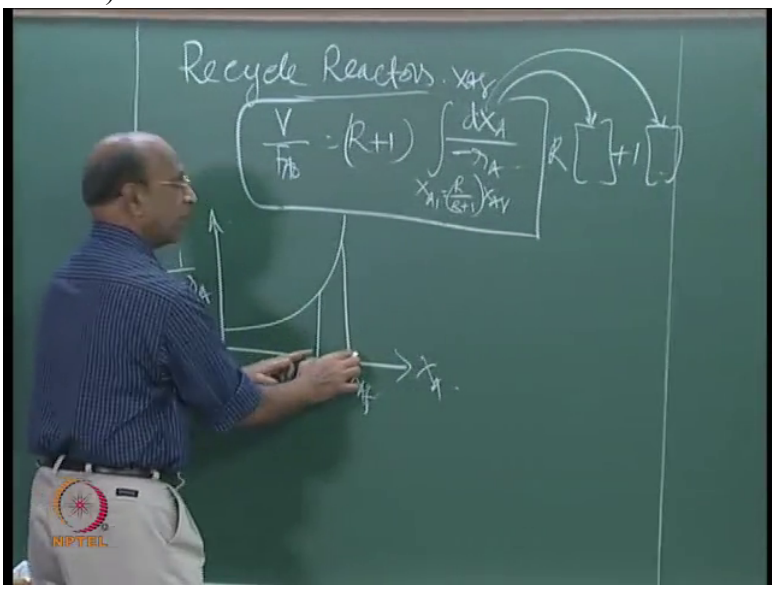

Because this one is starting from X 1 to X A f but only this part because R is

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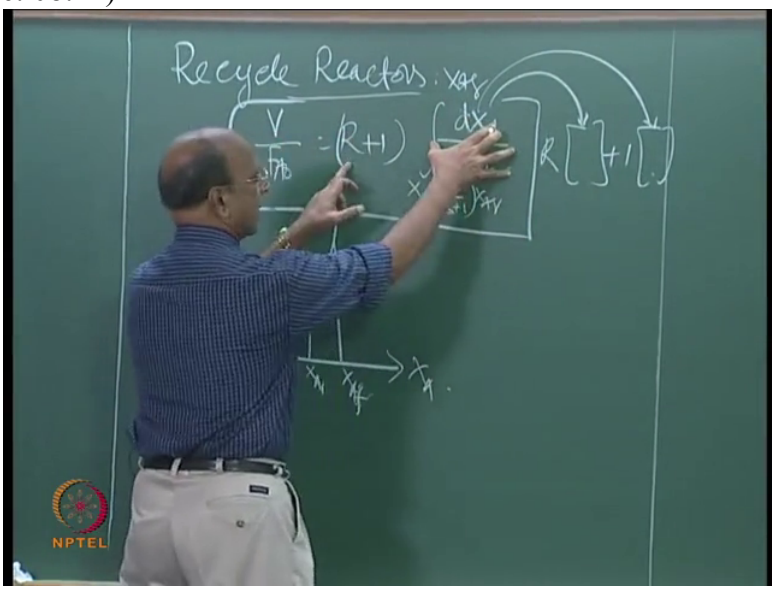

this one, here, this one.

So now what I do is we will take the equal areas that means I will just make this one as rectangle, not exactly like here, slightly above because this area and this area

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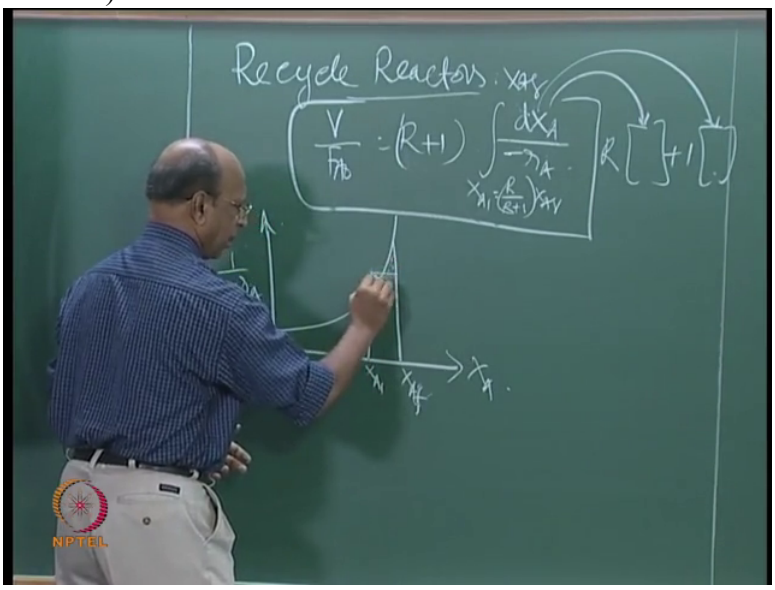

is like our normal way of finding out area under the curve, Ok, if we make rectangles and count the rectangles so that this width and height if I know, what is the area I can calculate. Ok, so now this is the one. The other one, yeah this is 1. Ok. This is 1.

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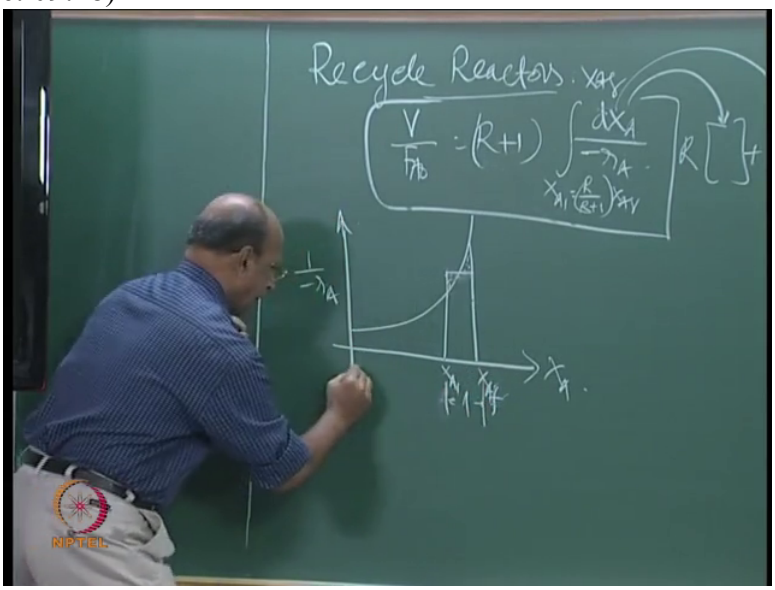

And the other one must be R,

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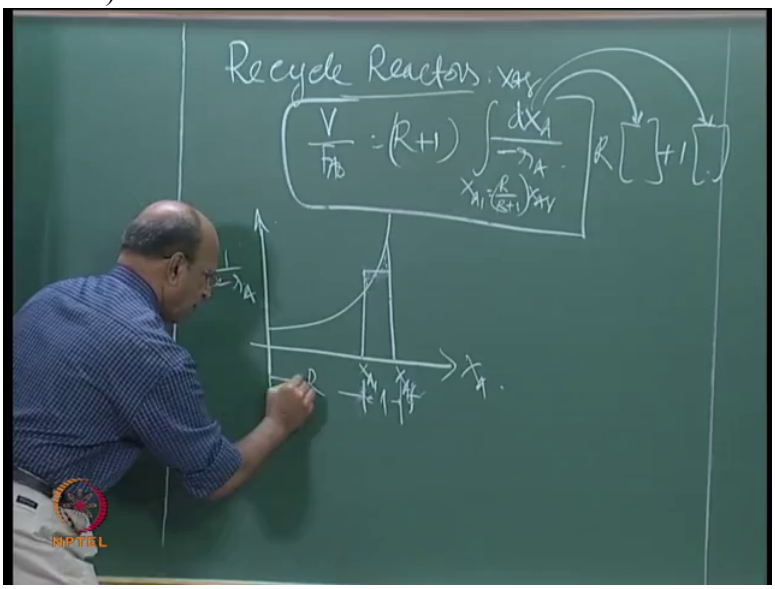

this is this integral,

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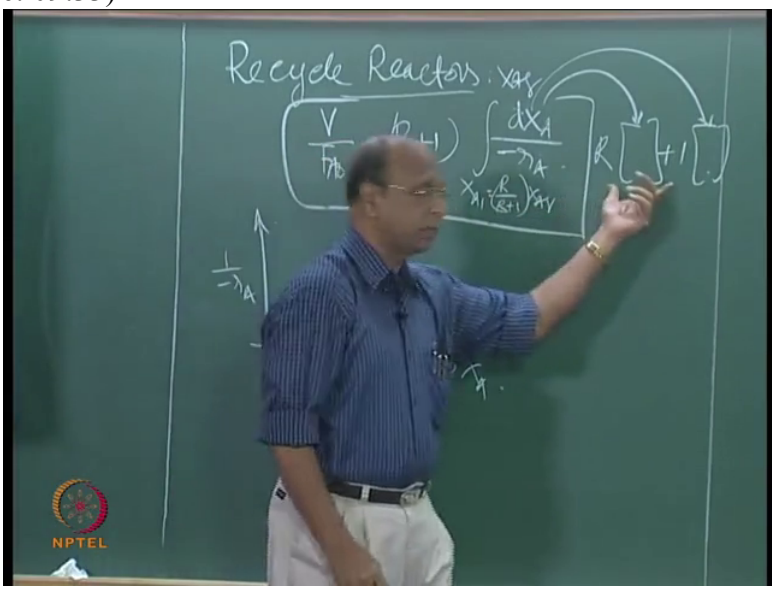

R times this. So now how do I get back? I have to, so this is the total area. So what we are trying to do is, anyway by drawing this what we are trying

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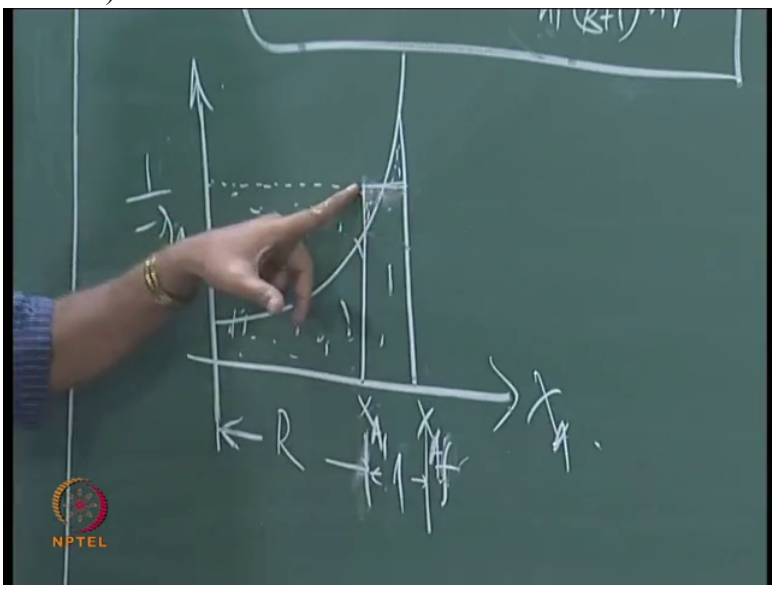

to do is that we are averaging the rate. Correct no?

Here I have one rate; here I have one rate, 1 by minus r A, 1 by minus r A.

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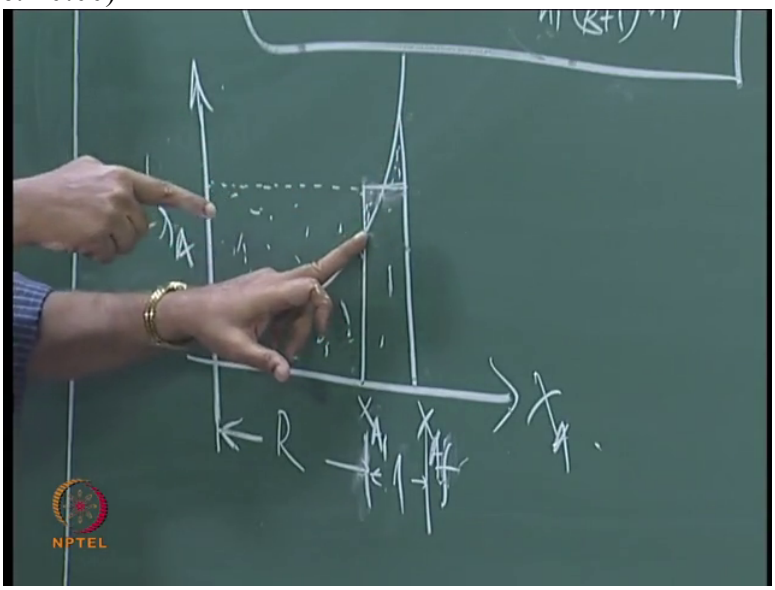

So somewhere between averaging, by taking this area, this area, right? So this is the average rate, right? So now the total area, graphically if I do, then this is the area which you have to take for V by F A naught.

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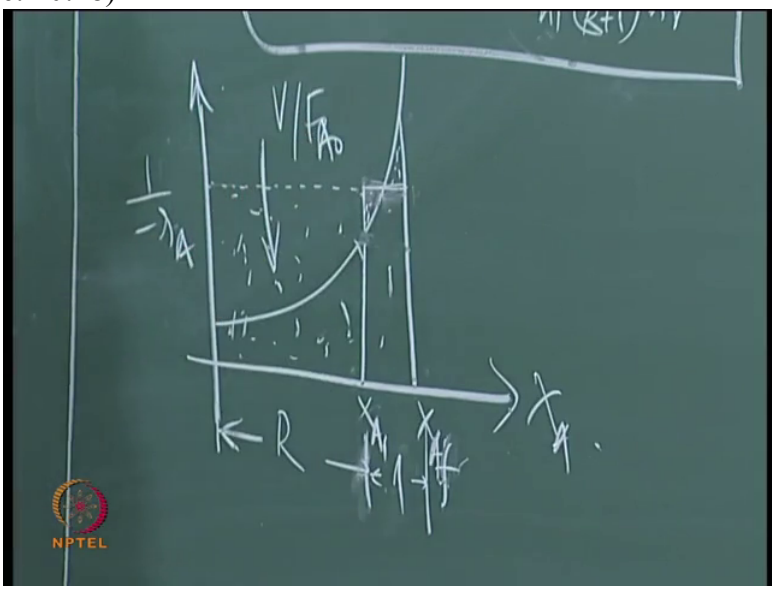

So now you see, again I split this equation. So I have one time this integral, that I know.

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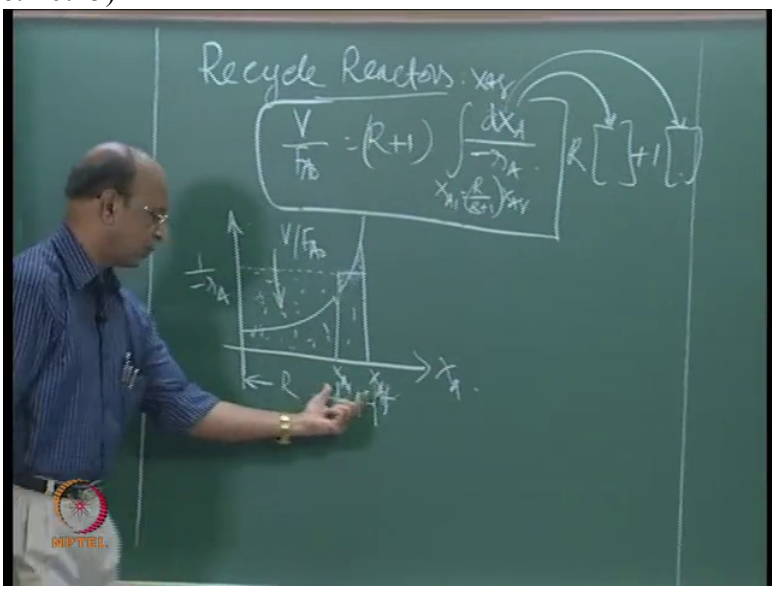

The other one must be

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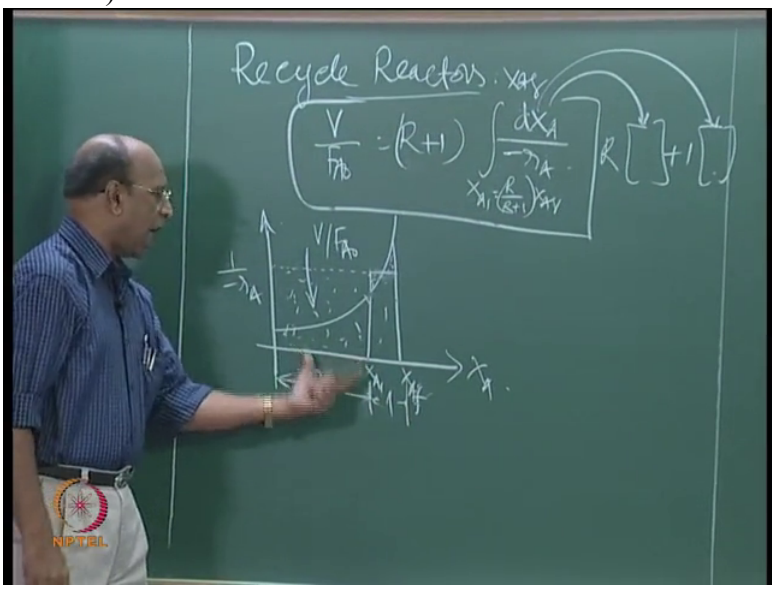

R times of that. Right. So this one alone I take and then I will average and make a rectangle. And this must be R times of, because this area, I think it is not difficult. If you are able to really catch the point but catching point is important, it is not difficult.

The reason is that you know I have taken this area separately only with this component and then made it as a rectangle, Ok. The other component is how much of that? Because it is same, R times of that. But you can also prove it beautifully. I just leave it to you again. You can also prove with equation.

So that means here, from here to here,

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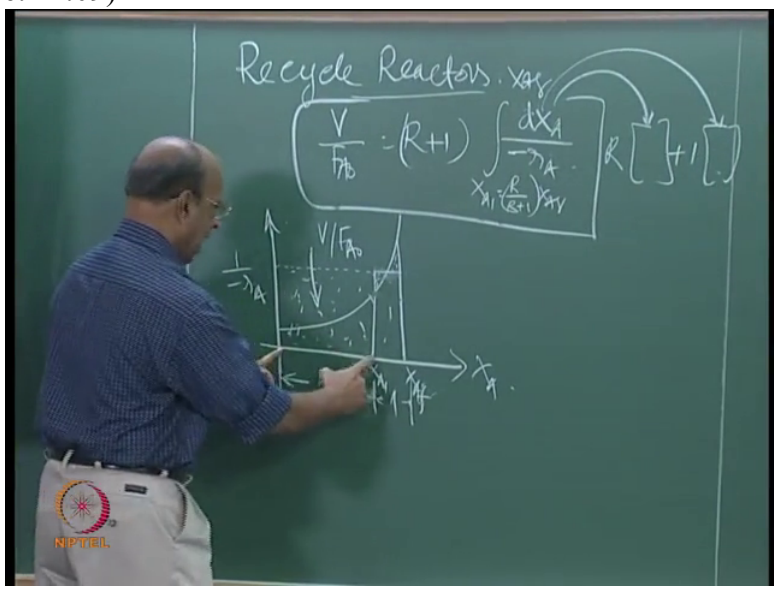

I have R times this 1 by r A, average, here at this point, I have 1 by minus r A,

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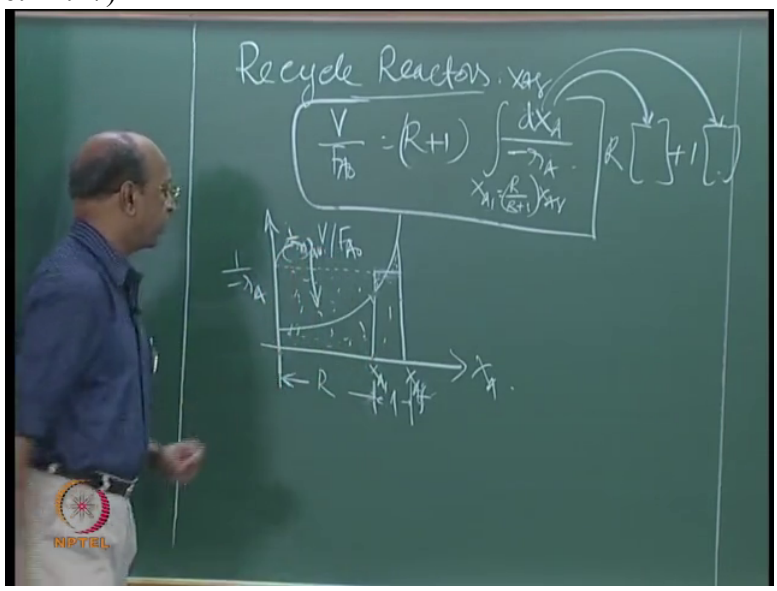

average at this point, right. Because it is not the actual rate here. Actual rate here, It is the average rate I have taken in between, right. That is why I am able to take the rectangle area by simplifying that this area and this area is equal.

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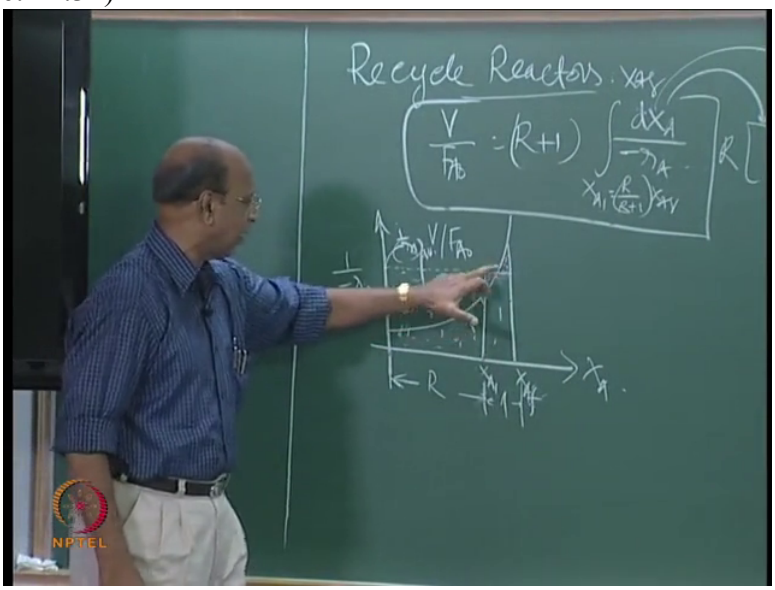

So now we will get 1 by minus r A average, right?

So mathematics cannot go wrong

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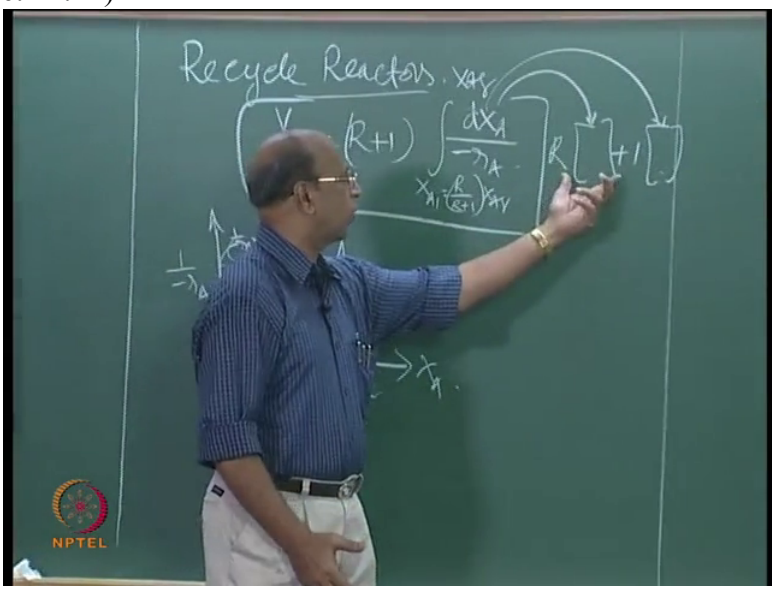

and this one now says that the other thing must be R times of this area.

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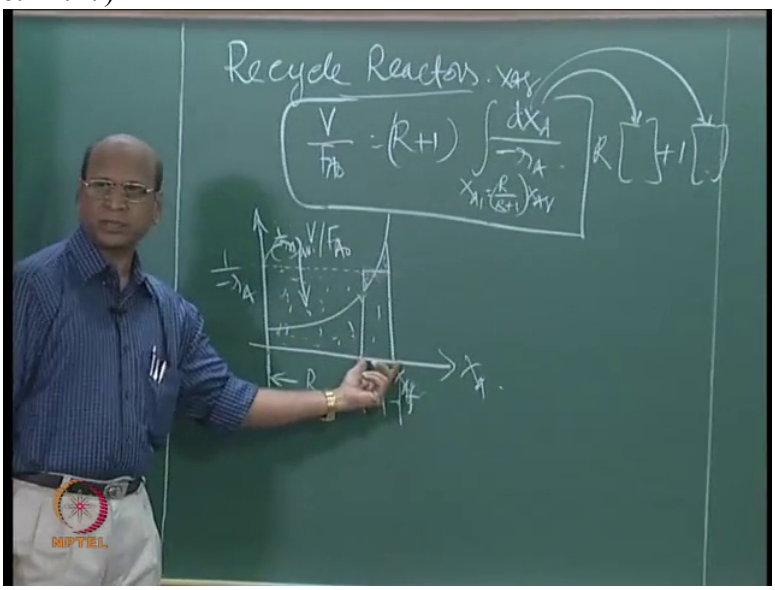

Now prove that, this is only graph. You can also prove that using that equation, using this graph and then you can say that this area plus this area must be equal to X A f, correct no, this is 1 by minus average

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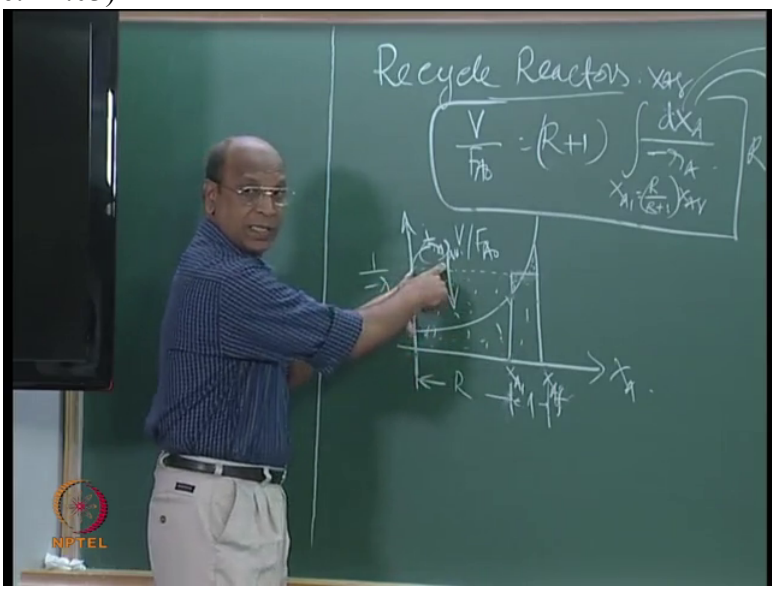

into

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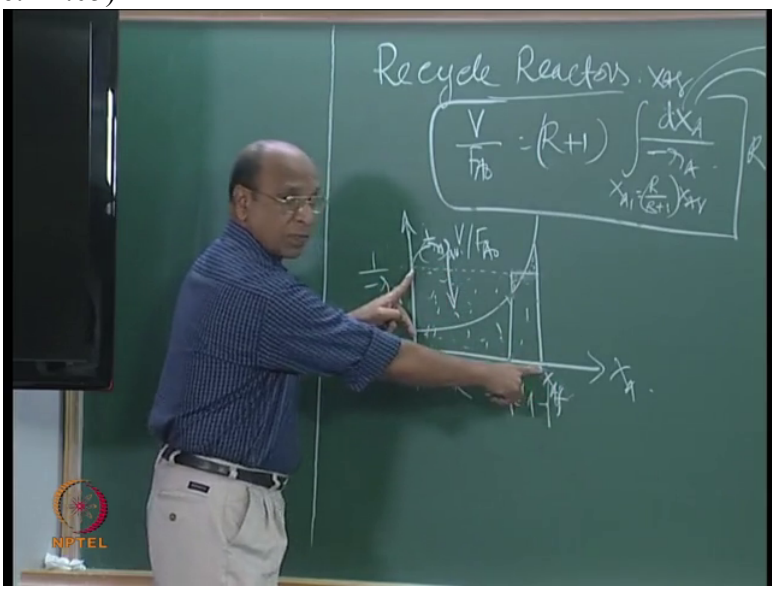

X A f, total area, total area equal to X A f by minus 1, 1 by average.

Or otherwise if you are getting confused with that, first I write X A f, all L K G, average, this is x,

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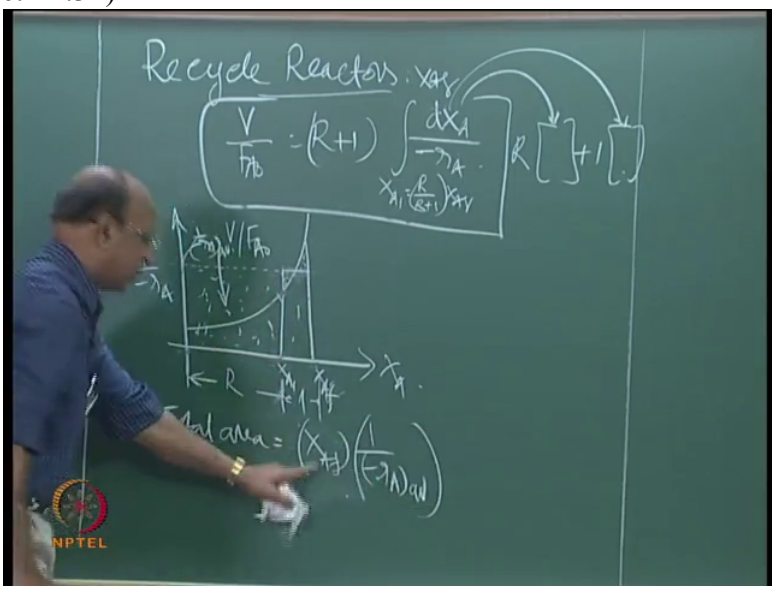

this is y, this is x, this is y, Ok. Otherwise if I write X by F A in this one, you may get confused again. This one

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This one

(Professor – student conversation starts)

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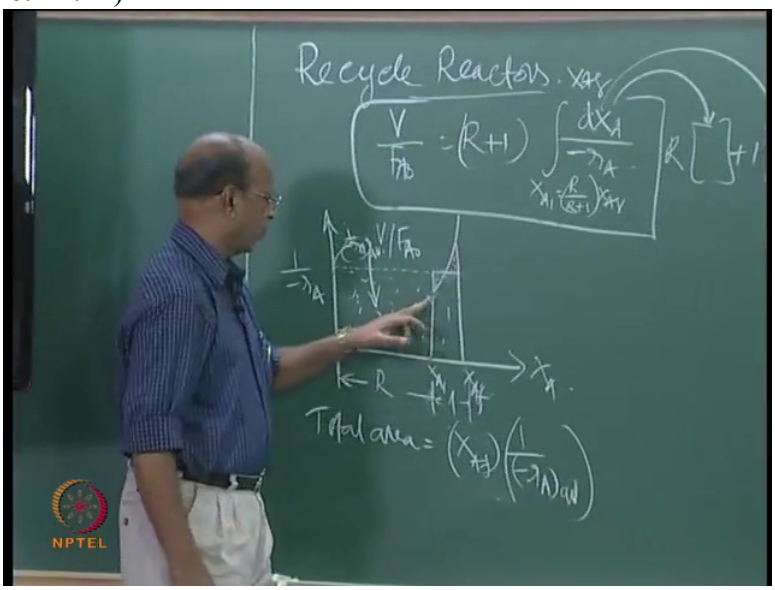

Student: Why did you go above?

Professor: Why did you go above that?

Student: 0:12:50.0

Professor: Yeah, where is the rectangle? How can make that rectangle? If I make this one as rectangle then what happens all this area?

Student: 0:13:03.5

Professor: This part of the integral, again I think probably I have to write. So this one X A 1, X A f, d X A by minus r A plus X A 1 X A f, d X A by minus r A Ok?

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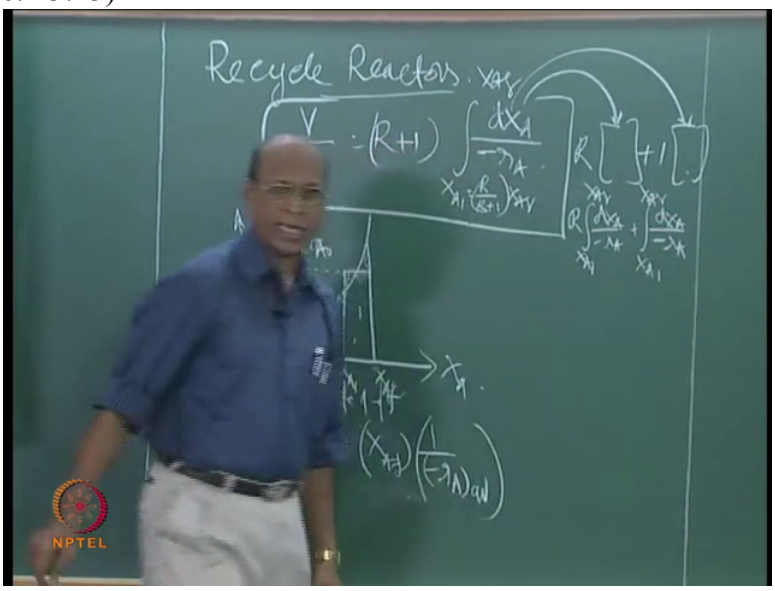

So what is this? That is this. If I do not take this, this is the entire

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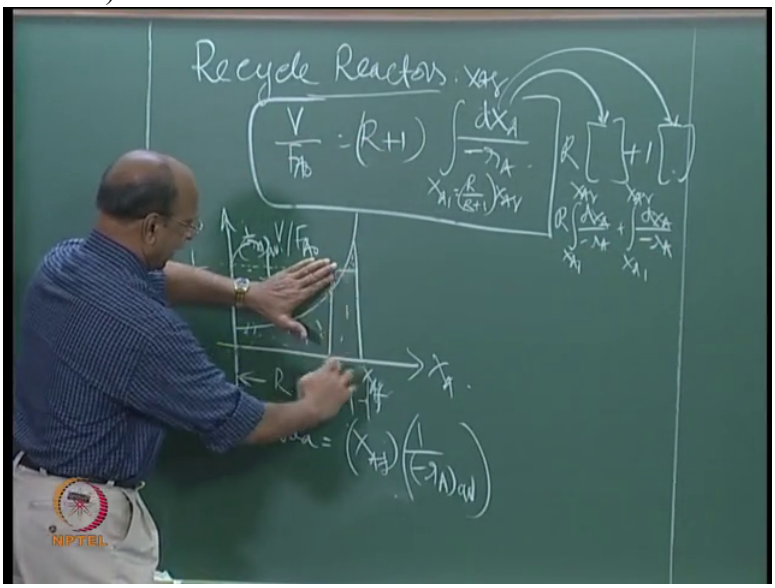

area. That is the entire area.

(Professor – student conversation ends)

So for me it is easier to have this average rate

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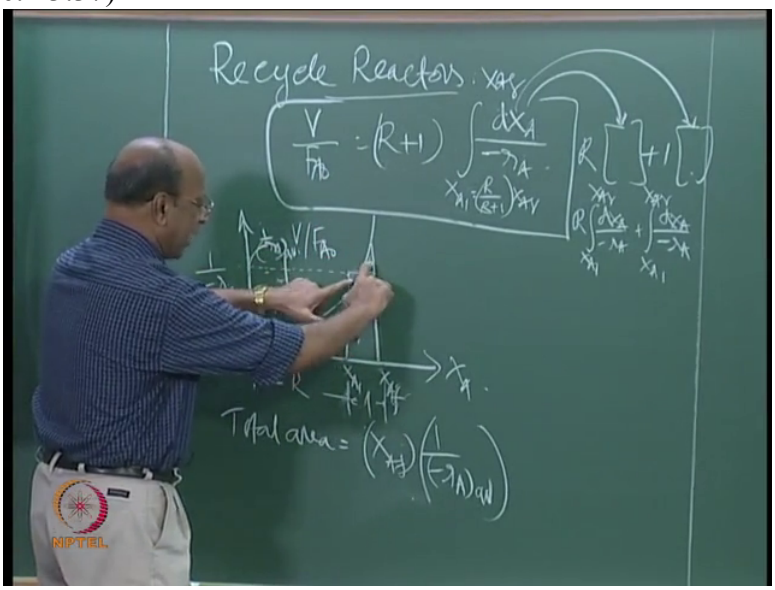

and then extend further. Because once I averaged this rate, the other one must be R times of, as you said if I leave it, how do I average? I mean how do I say that what area I have to take?

(Professor – student conversation starts)

Student: 0:13:50.5

Professor: It is not that. It is not C S T R separate. You cannot simplify things, no. If I draw here only 1 line, that represents that that is separate

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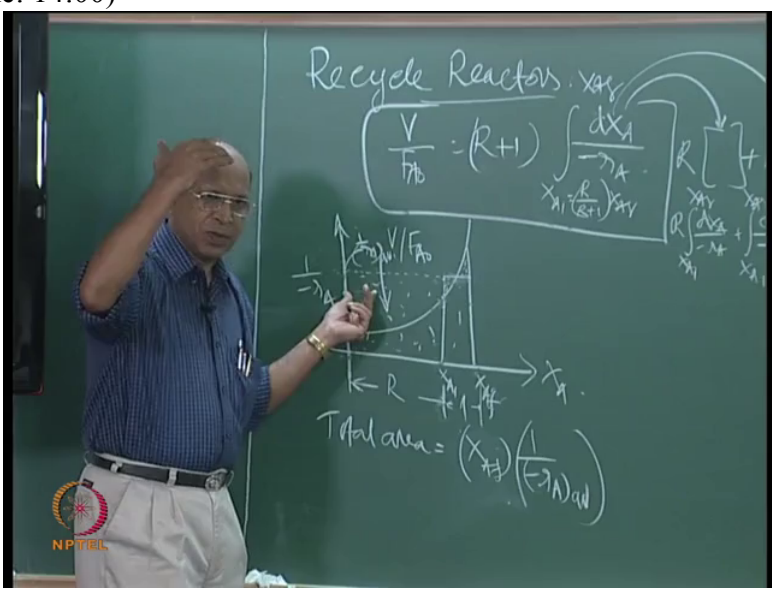

C S T R. It is not C S T R; I mean where is C S T R?

(Professor – student conversation ends)

So the combination of C S T R, some kind of mixing, combination of mixed flow reactor both together is there in this area. Ok So that is the reason why. This if you understand, this must be R times of this.

Now what we have to do, see I am trying to tell you to solve is, see I am giving these kind of problems only to make you to think in your room. And rich people are getting richer and richer and richer, poor people are getting poorer and poorer.

I think two extremes we are having now, plug flow, mixed flow. Ok. One is most inefficient, another is yeah, very, very efficient, that way only I am telling. Ok, this gap is increasing. We need something like recycle reactor. Because right amount of mixing where everyone has equal wealth, correct no? Yeah. I think equal wealth means I am not telling that you share the wealth. At least food you share. That is all.

So this is what is the general one, I think this is understood no? And you can now prove beautifully that the total area

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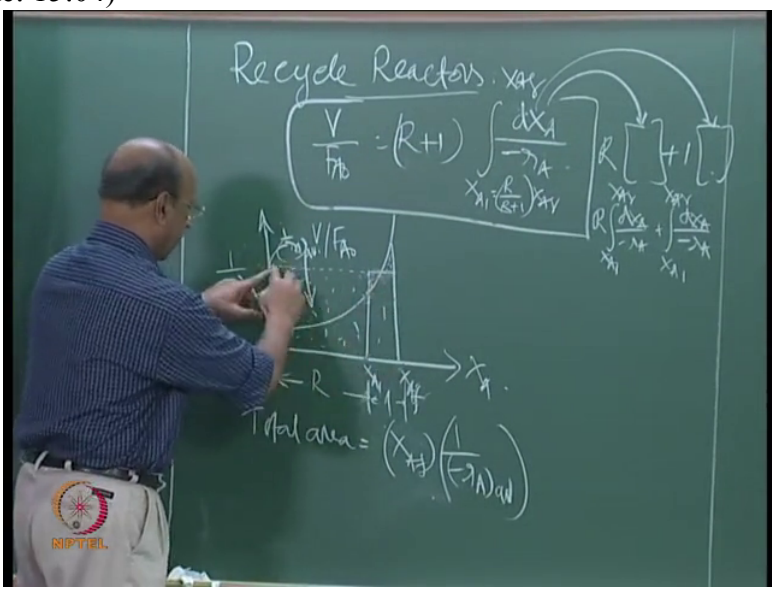

is sum of this area plus this area. We will take only the rectangles.

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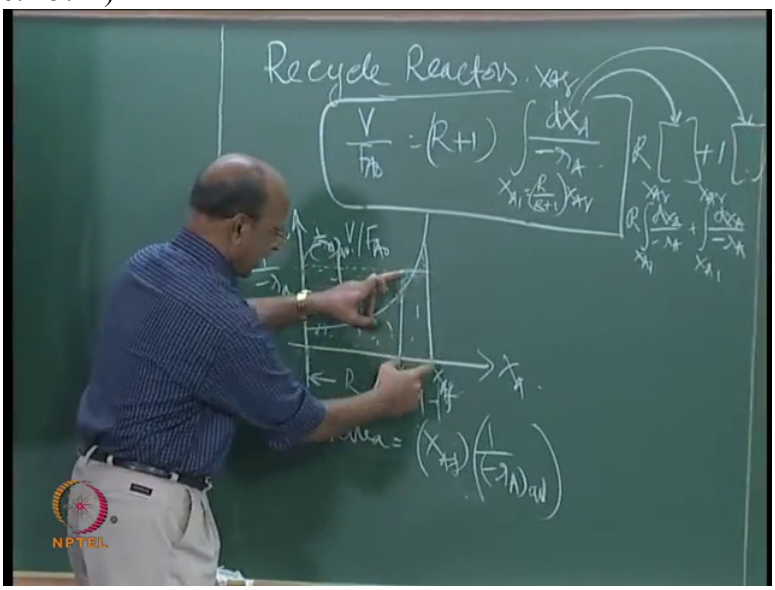

This area you first take and you know the limits, what is the area; it is a graphical thing, it is a figure. So then this must be R times of that. Add those two and show that this is X A f by, or X A f into 1 by minus r A average. Average is this. That is the average

(Professor – student conversation starts)

Student: where is the R times

Professor: Yeah this one.

Student: How will the graph 0:15:34.7

Professor: Equation itself.

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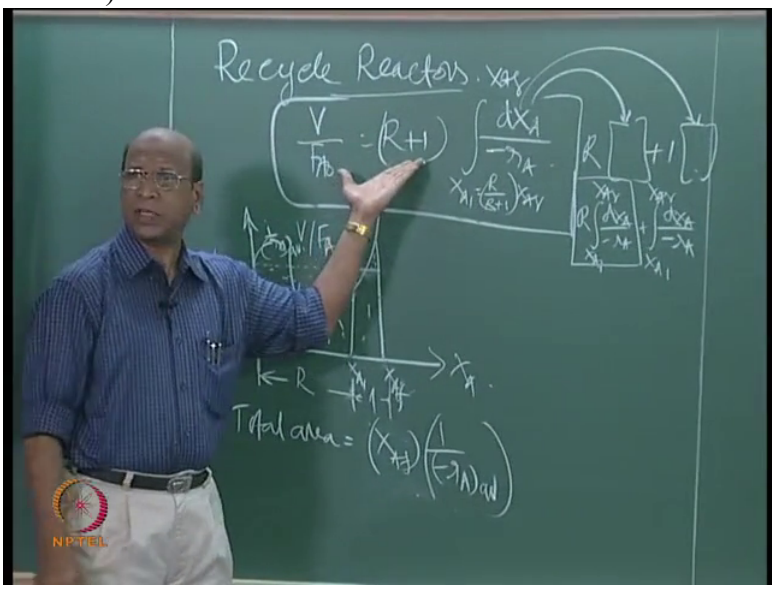

In this equation

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only it is there. This R plus 1 into integral of this entire thing. I just split that into R times of this plus 1 time of that. That comes from the equation itself, no. From the basic expression itself in the derivation, that equation comes. You were there on that day. I think you were there. Yeah, the equation is R plus 1; the equation is correct, no? Yeah, which one?

Student: X A 1 X A f in the graph.

Professor: X A 1, X A f

Student: In the graph

Student: Graph, sir

Professor: Yes, X A 1 to X A f.

Student: That we have made it identical, one unit.

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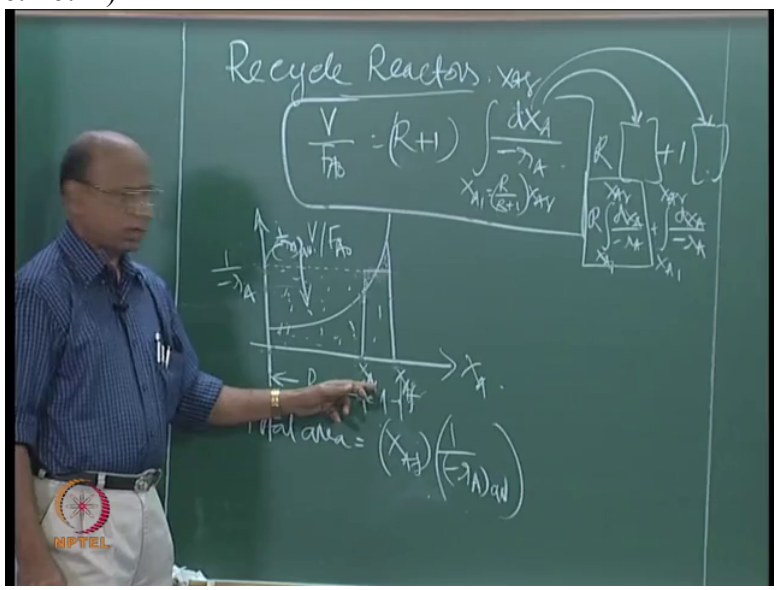

Student: No

Professor: No, I am just plotting only this.

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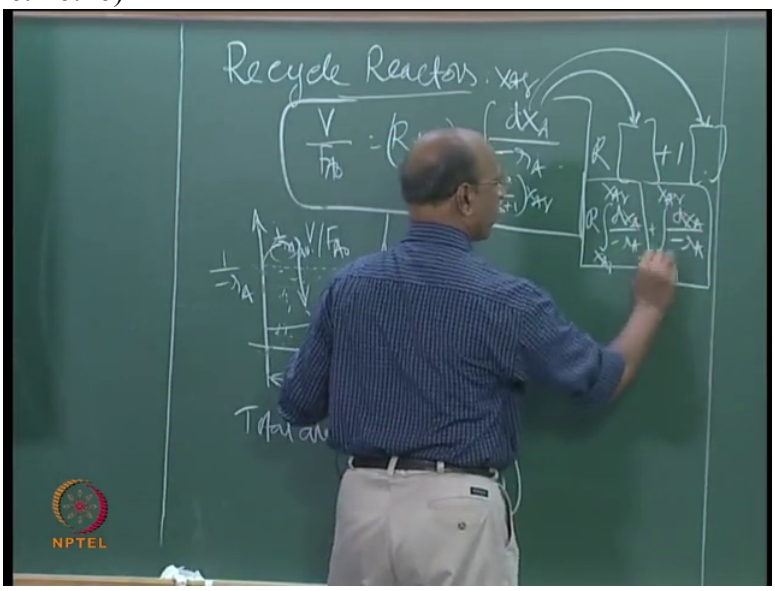

Student: I understand

Professor: See area under the curve between X A 1 and

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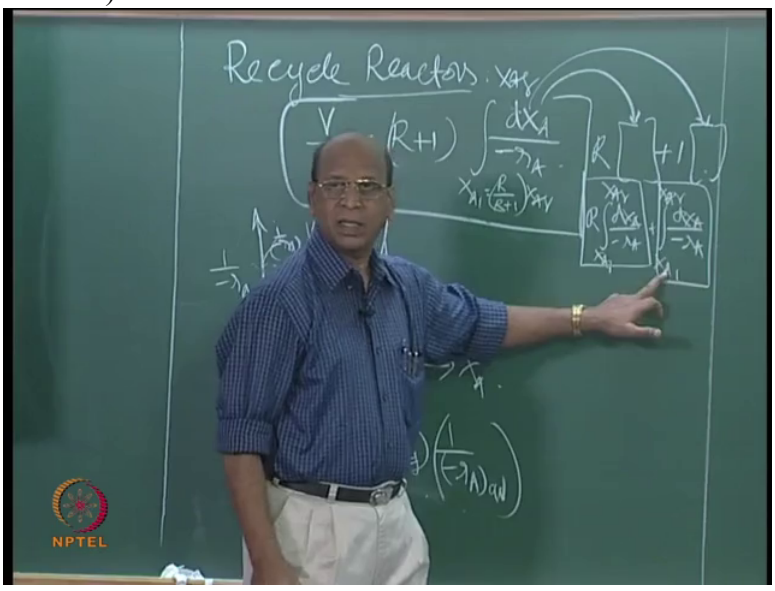

X A f because my area, simple calculus no, simple calculus Ok,

Student: How can,that area, it cannot...

Professor: Yeaah, you see, like this you have and when I ask you to calculate what is this area, how do you calculate if it is x 1 and x 2? One thing is to find out all this, that is Ok. Area, total area under the curve.

(Professor – student conversation ends)

Another easiest thing is make this, so this area equal to this area so

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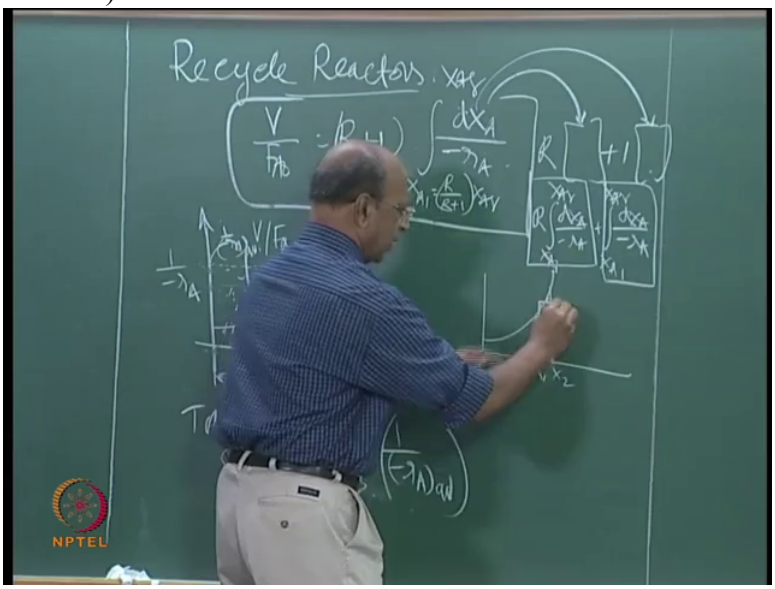

this height

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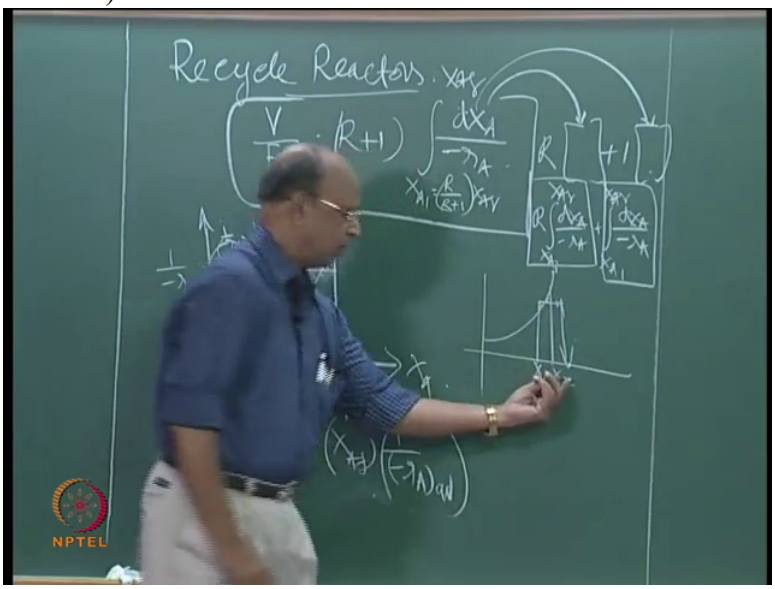

multiplied by this width. So this is x 1 and x 2, x 2 minus x 1 into this height y, so the area is y into, because you are starting with zero,

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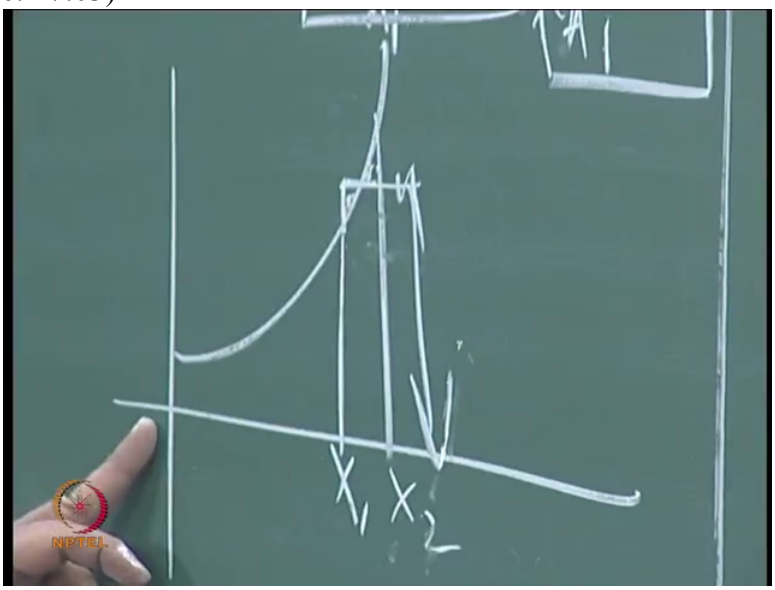

so y into x 2 minus x 1.And the other one is R times of simply this, if I take this one as some kind of alpha, this is R times alpha

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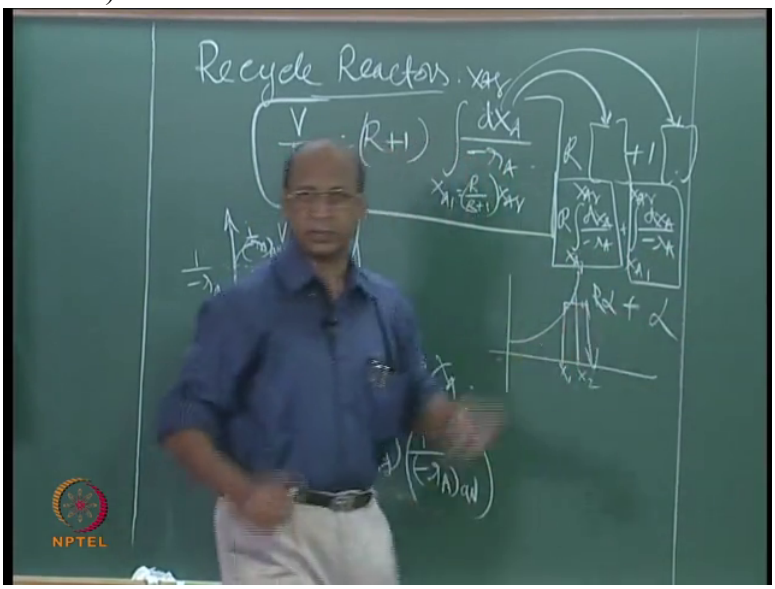

...area

(Professor – student conversation starts)

Student: This is alpha, and I accept that how this is R plus alpha,

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but how do you know that is R? That was asking also

Professor: Ok, that is what I am asking you to prove.

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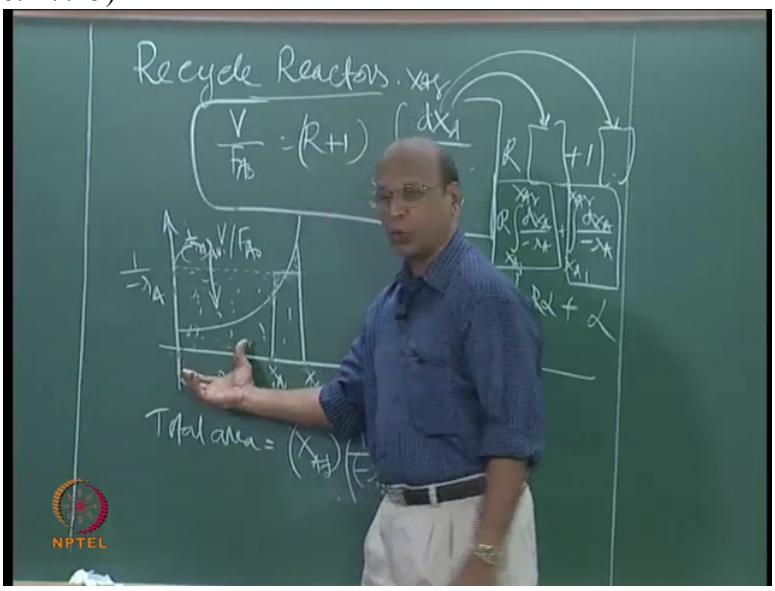

Student: (laugh)

Professor: That is what I am asking you because you know in this case

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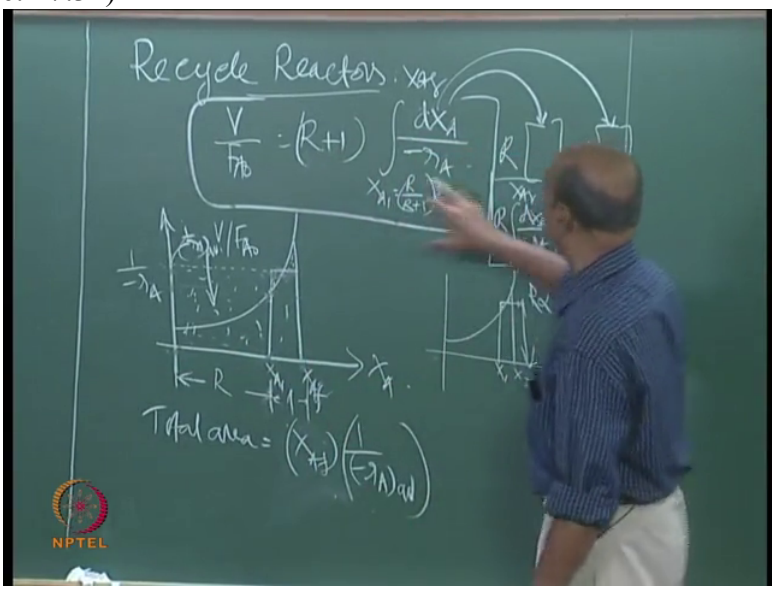

this is the total equation, V by F A naught, Ok Abhishek;

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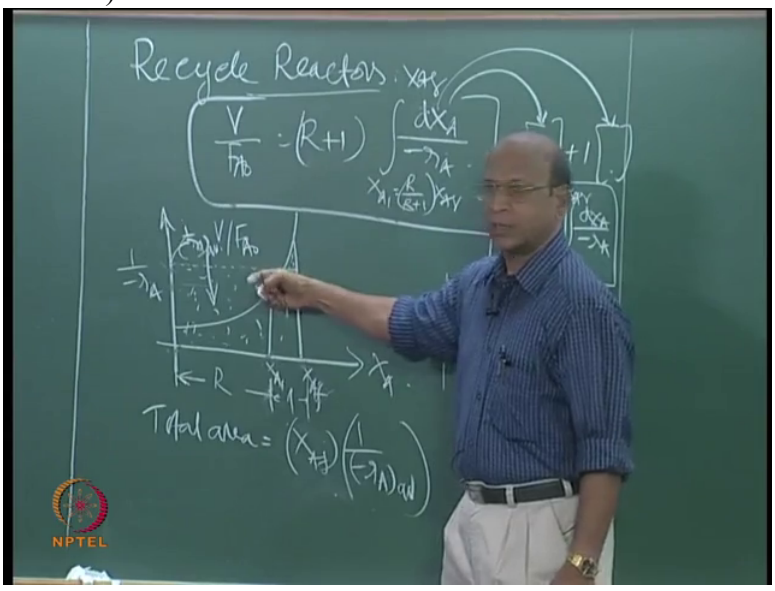

this is the total equation, right? V by F A naught. Now I have this part as simply

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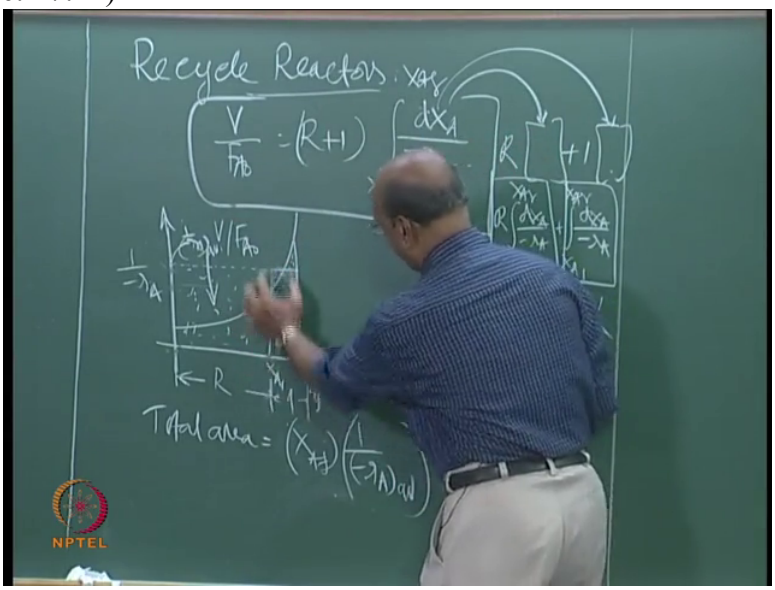

1 time of simply this area, right. So this overall thing should be, because it is starting from zero, x also

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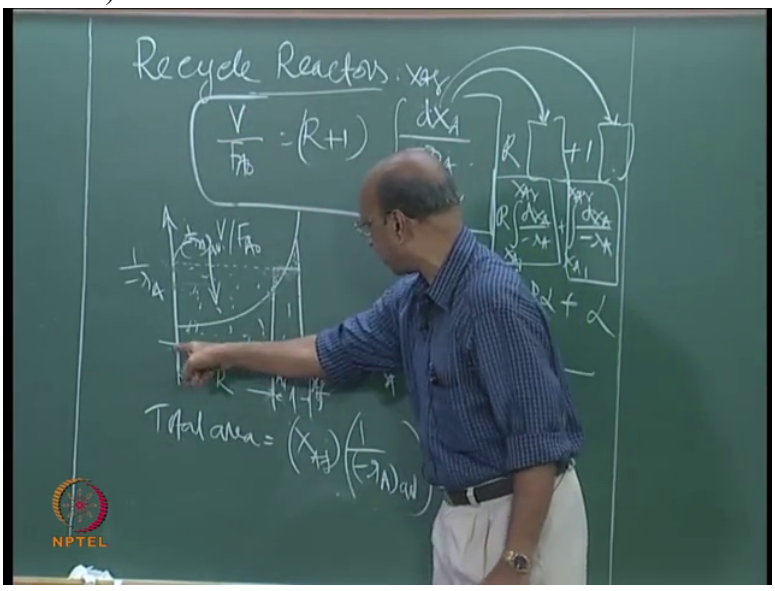

starting from zero that is what this

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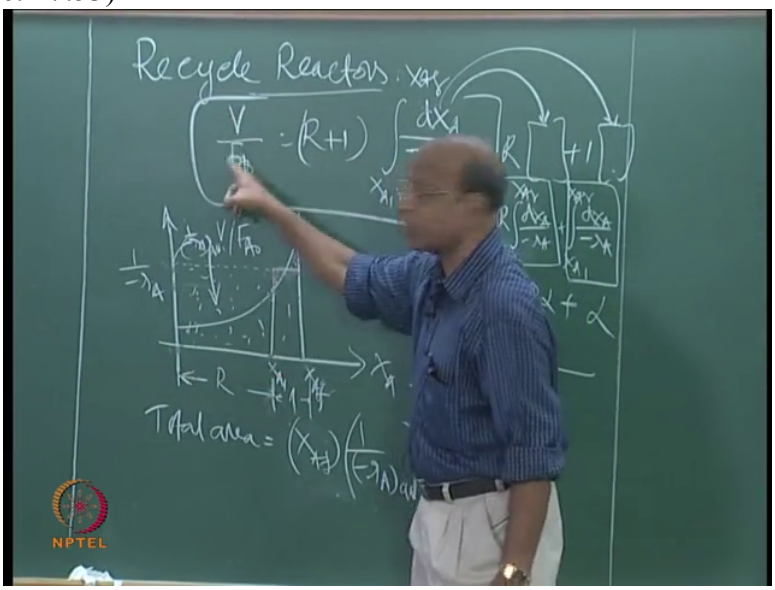

equation tells.

(Professor – student conversation ends)

Because when you take the overall mixed flow reactor, in the beginning you have, you do not have conversion to zero. Only at the time of entering, because of the stream coming back you have a different X A 1, that is X A 1, right? So that is why the coordinates are from zero to X A f, right? So now the total area when I take this as 1 unit...Yeah but this...

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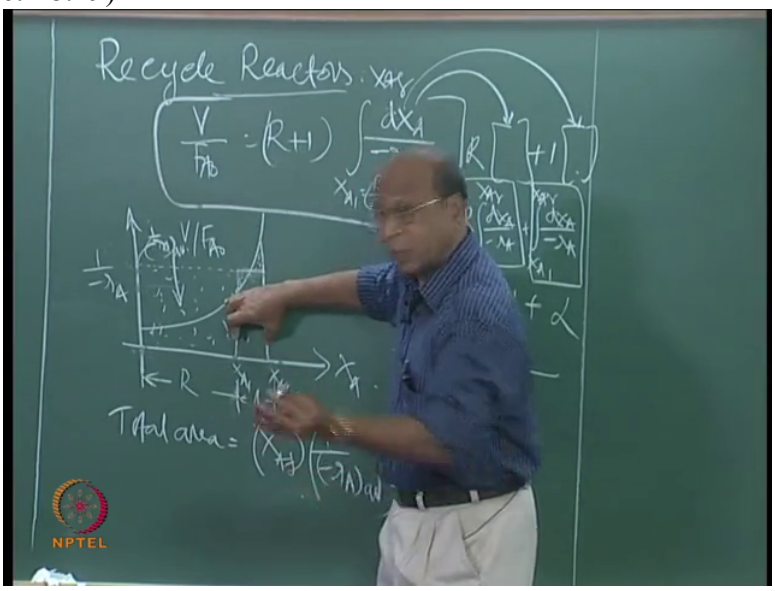

(Professor – student conversation starts)

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Student: This is R time

Professor: Yeah definitely

Student: Then R equal to X A f minus X A...

Professor: You see,

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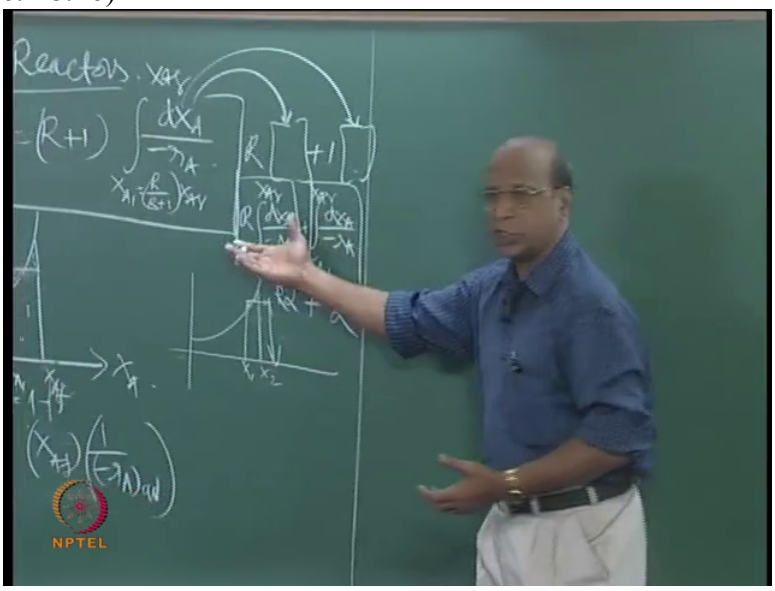

this equation, this equation automatically tells if I know this area, automatically this must be R times of that which is the total area because x equal to zero onwards it is starting, Ok. So that is the one, Abhishek

Student: 0:18:37.6

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Professor: Yeah, you do not have a choice then.

(Professor – student conversation ends)

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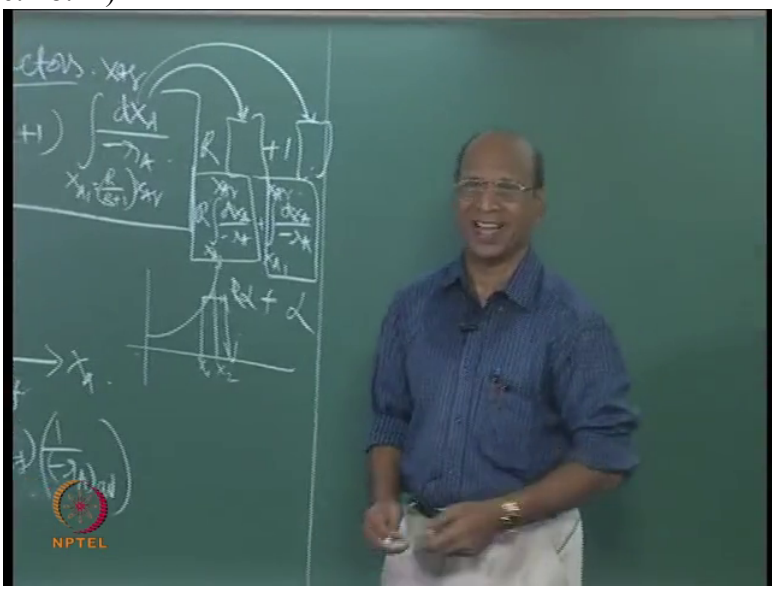

No, no I think we should be able to do that also. You do on your own. If you are able to do, I will tell you Ok later but you do it, you try to do it. It is not difficult. It is not difficult. Please do not think that it is a difficult concept, Oh my God, very difficult it is! It is not very difficult at all. Because we do not know how to use our calculus properly, that is all.

Very simple thing. You know integral y d x I know. The moment I put our normal plug flow equation as d X A by minus r A we think that it is totally different. That is simple calculus

area under the curve. That is the reason many students also not able to answer why should I take total rectangle for mixed flow reactor. Plug flow reactor, some people tell.

You know I am talking about single mixed flow reactor. Why should we take that rectangle? I can tell you, now you know or you may be knowing even some of you earlier.

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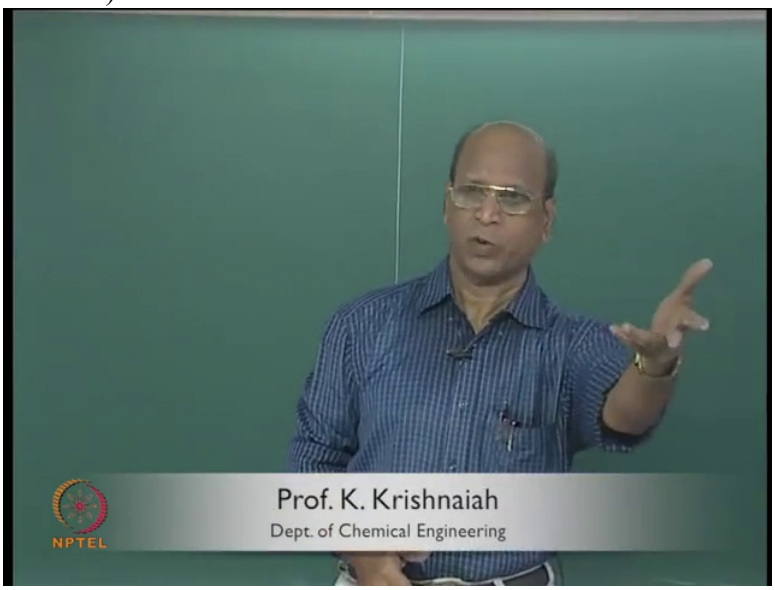

But my experience with many students is that they do not know why they are taking. It is simply nothing but that is x, this is y. But the x is, I mean y is not y. y is 1 by minus r A. That is all. That is so simple. That is the area of a rectangle, x y.

y is written in terms of 1 by minus r A. The moment we say that, that is a problem for us. d C A, if I give d C A by d t equal to some right side some C and then ask you to integrate you will have lot of difficulty. Oh my God what is this! Totally new. But if I convert that exactly same thing as d y by d x equal to x, you will easily do it.

Because beyond our schooling we are not learning anything new. Ok and that d y by d x it is told that that

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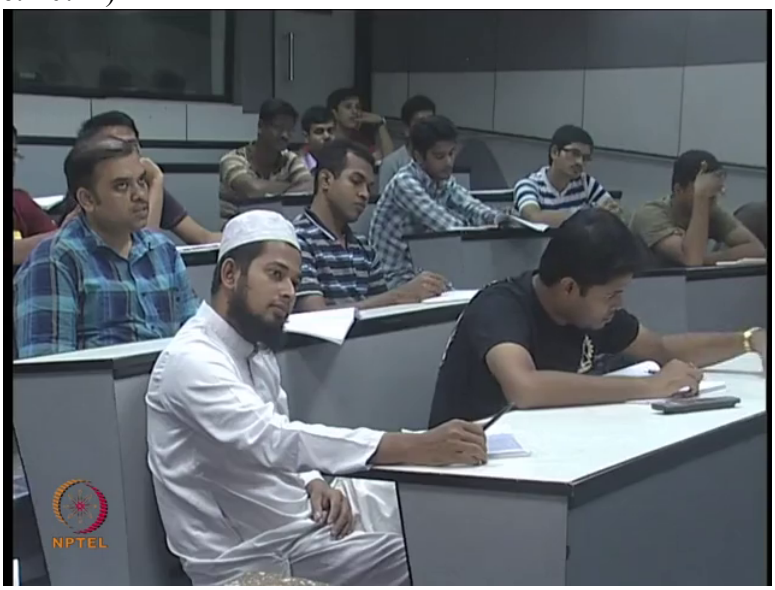

y can be anything; x can be anything, that is what also here. Here of course, x is X A, and y is 1 by minus r A.

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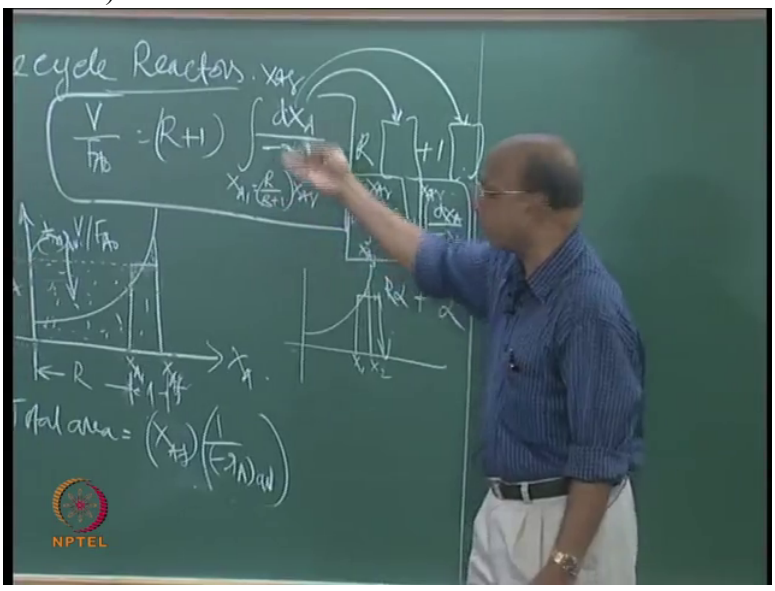

That is all what you have there. And we will say always x and y, because those are the general variables. It can be extended to anything.

And our mind is always compartmentalized. Ok, Ok x means x, y means y. And I cannot use anywhere else. If C A comes and t comes I do not know how to use it. And I am not teaching anything extra except that you know simple calculus where this area under the curve I have, I have

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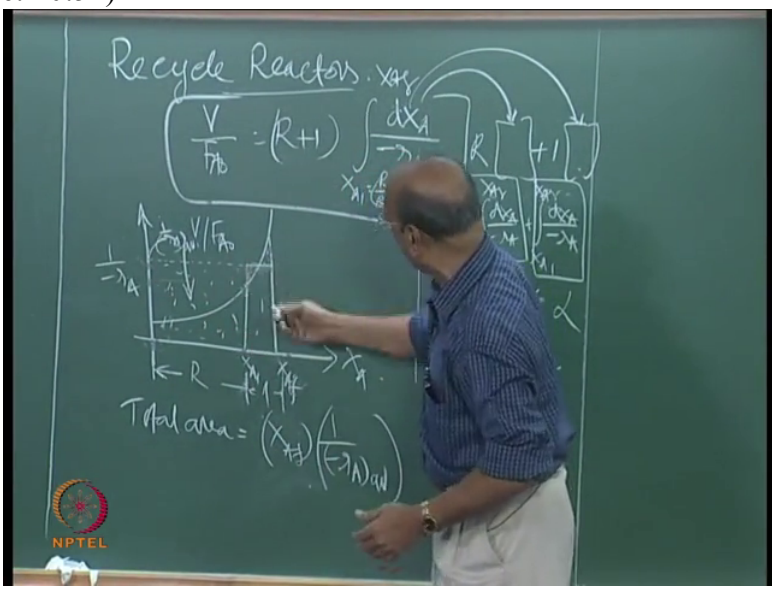

simplified as a rectangle instead of this shape.

Now this equation if you believe that it is correct, that is correct only what we have written material balance and all that, Ok. So then this total area must be R times of this. Then only I will get total area this one, that is X A f into 1 by minus r A must be equal to this area plus this area. Ok.

I know this area. This one by minus average into X A f minus X A 1. And what is this area, 1 by minus r A average into, yeah into zero to X A 1, simply X A 1 and that too, R times of that. You prove that those two will give you this entire thing. That is all. And I tell you this is L K G problem.

Because just graphs only we are drawing and then trying to find out that these two areas must be that area. Ok, good. Ok. So now if I very large, Ok small recycle ratios, Ok small R what kind of graph I get? This is X A and this is minus r A, Ok so like this I have.

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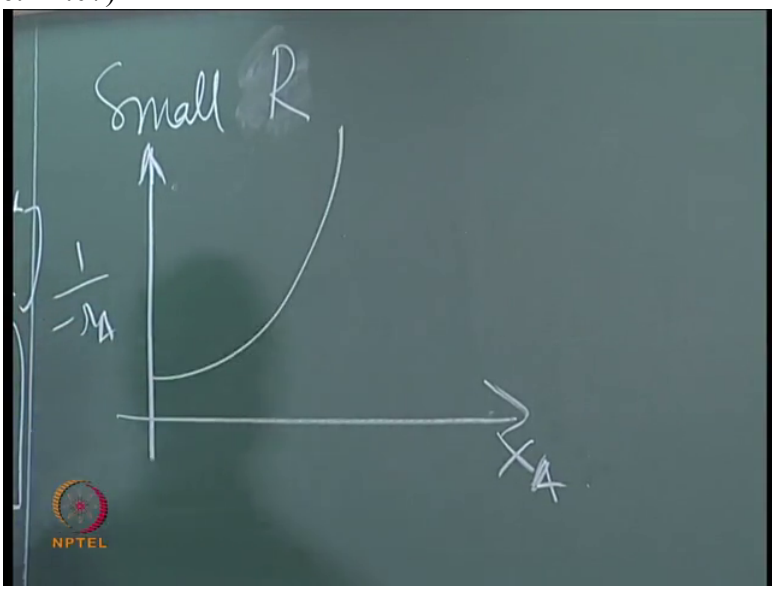

Ok Abhishek, how do I draw now? My X A f is known to me. Very small recycle ratio. Yeah, somewhere this side.

(Professor – student conversation starts)

Student: To the left

Professor: Yeah, why?

Student: R is small.

Professor: R is small means

Student: Maybe area under the curve...

Professor: Ok, area under the curve means

(Refer Slide Time: 22:34)

R equal to very, very small means R equal to zero means what?

Student: It is plug flow reactor

Professor: Total area under the curve, right total area.

(Professor – student conversation ends)

So now we are saying that

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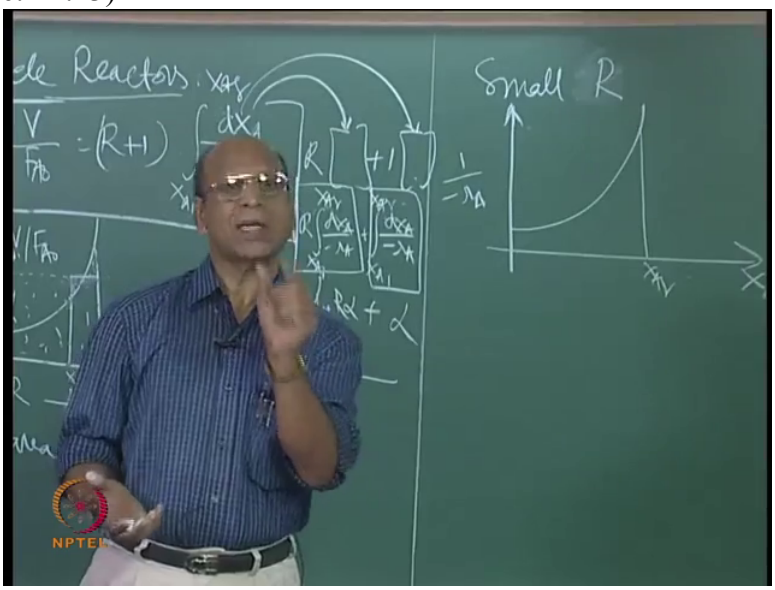

I have small R. So that means it may be slightly something there. So when typically R equal to zero, then I will have only small this one and then total area under the curve will be there, right?

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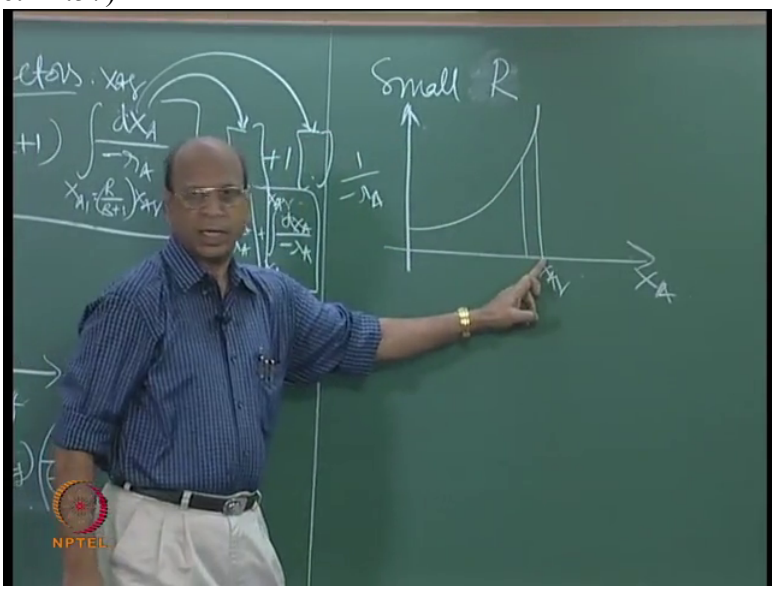

Ok, good.

So now when I have R is small means you should have somewhere here. X A 1,

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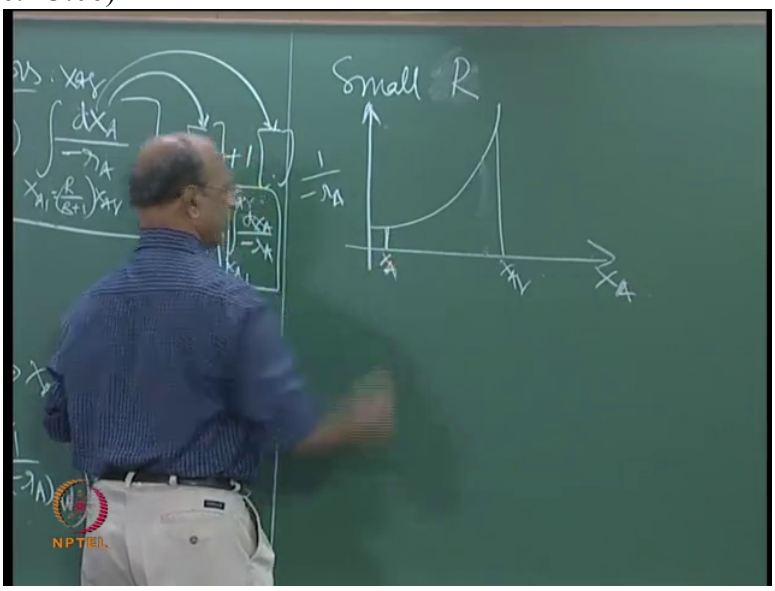

so this, actually this entire thing will be 1. And this will be R, that is very small.

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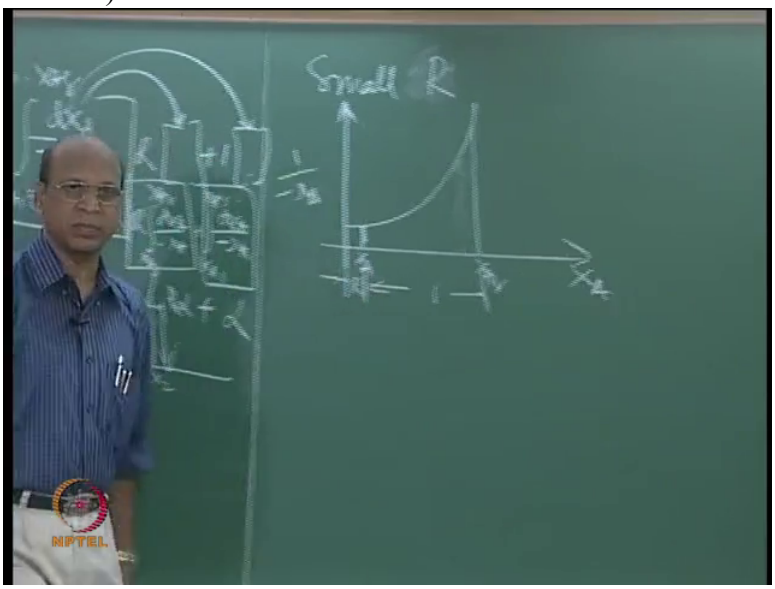

And now you see I have to do the same thing here. I have to; you know this is the one, small one.

So that means when I am coming here, less and

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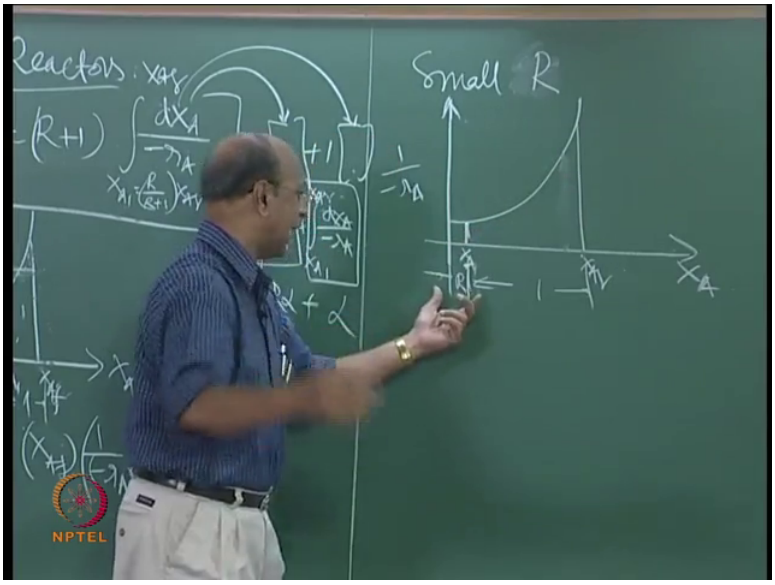

less R, that means the total area under the curve will be coming almost, you know,

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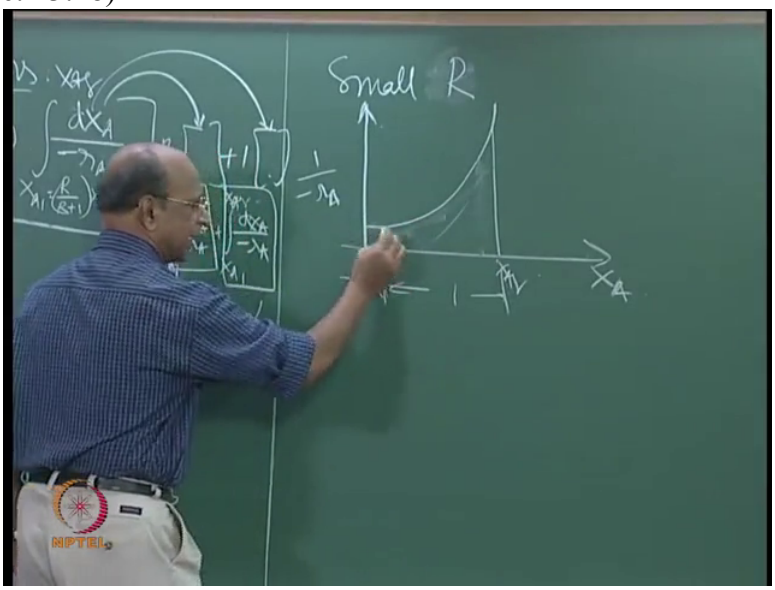

like this here, this entire thing. So, yeah this is for small R. Ok for large R? Anyway the other one.

So here what you have to do is, what you have to imagine is that this entire area under the curve is coming that means it is moving towards plug flow. Area under the curve, this is extremes what you are taking. And for large R, again we have this one, this is 1 by minus r A versus X A, same thing X A f, yeah.

So now I do not have to ask you now, only this much I will take, yeah.

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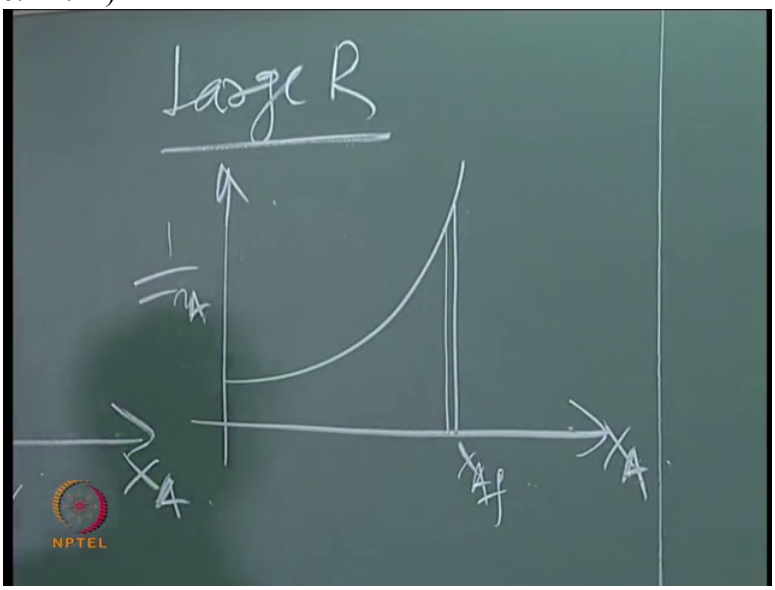

So that means Of course, here also I can, this average, now what is happening here? Yeah, this is V by F A naught. Ok, V by F A naught for large R a

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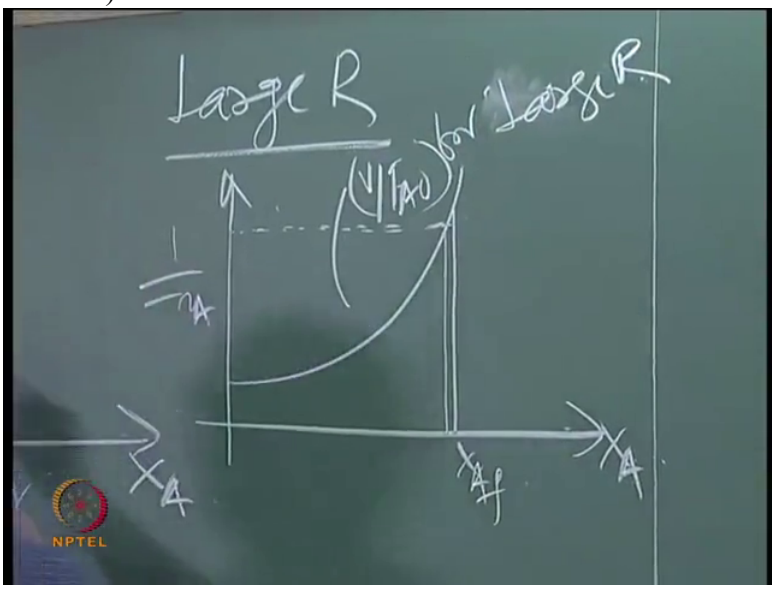

and here V by F A naught for, for small R, yeah.

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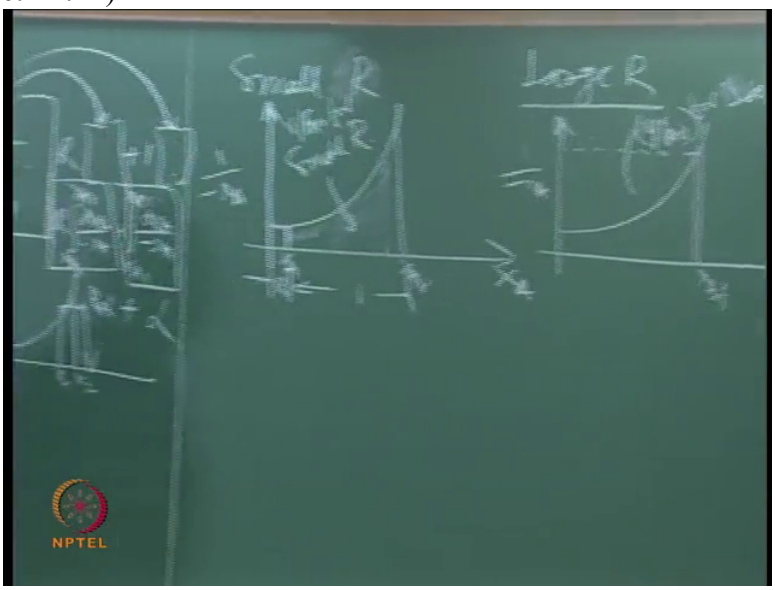

(Professor – student conversation starts)

Student: This small R, if you average the thing like that, so in that case how will you prove that small...

Professor: When do you average that

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when I am coming towards this?

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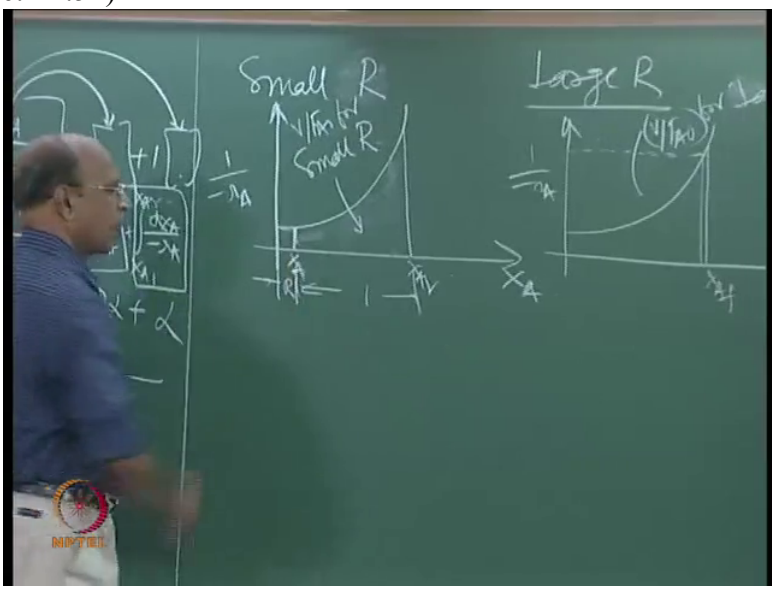

Student: You can...

Professor: How?

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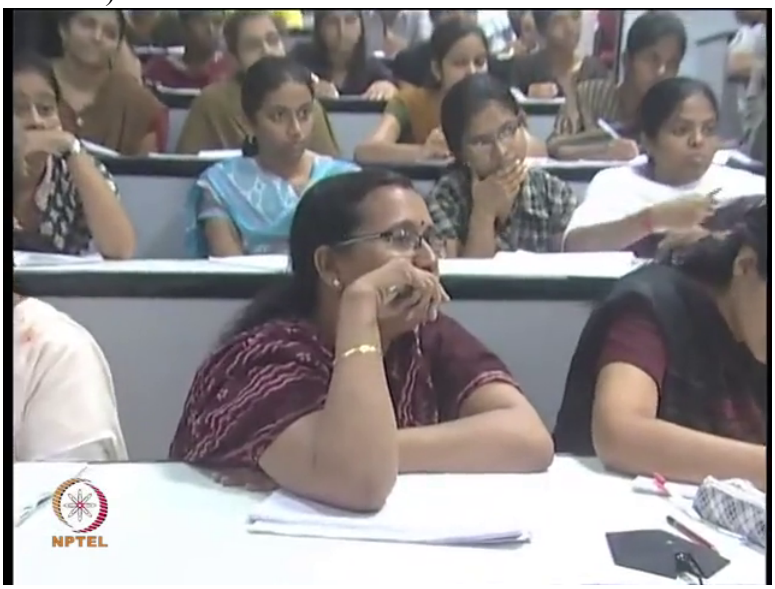

Because I cannot average this no, because when I have like this, this is equal

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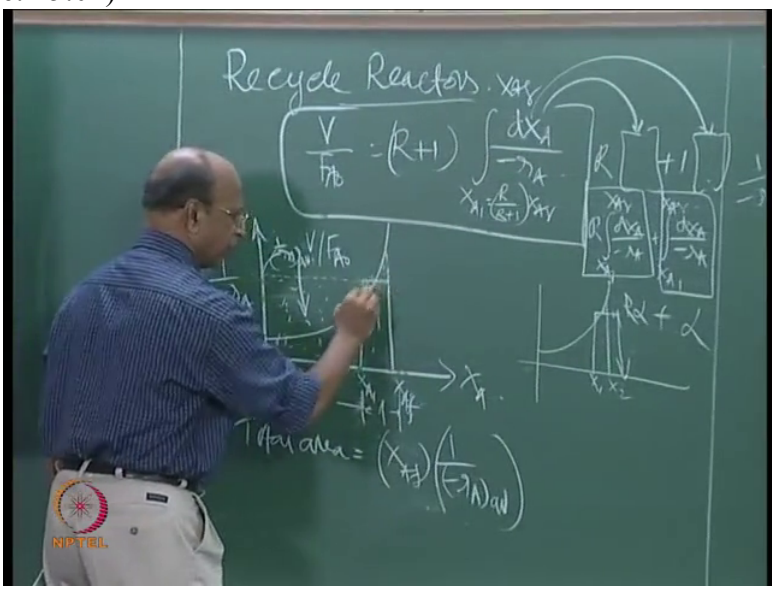

to this. But here itself I have right here, yeah. So I cannot go above this, no?

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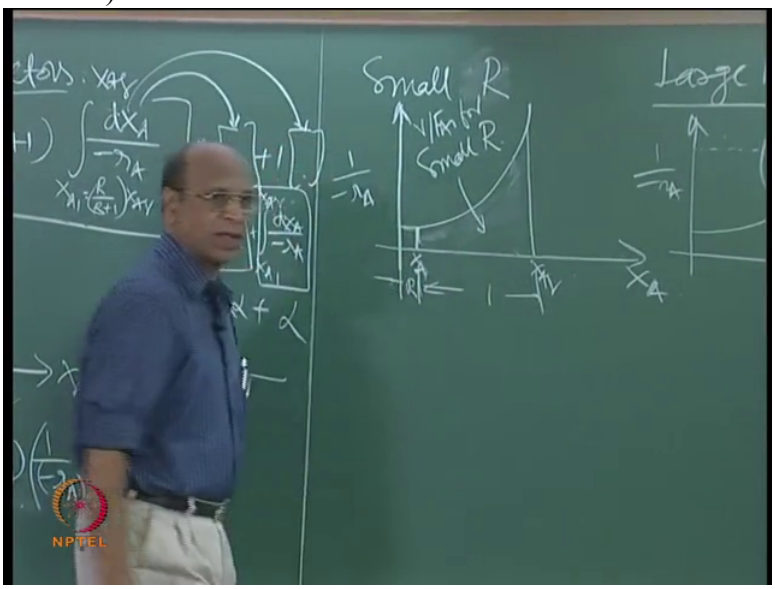

Student: Above that.

Professor: Good, that is good question, yeah. So now, yeah I can average this. This area

Student: It will be a rectangle, fine, Ok so

Professor: This is a rectangle but definitely we are now coming down

Student: Yes Sir

Professor: More and more.

Student: But how will you say that this area is R times that area?

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Professor: Which one? Yeah, yeah. This

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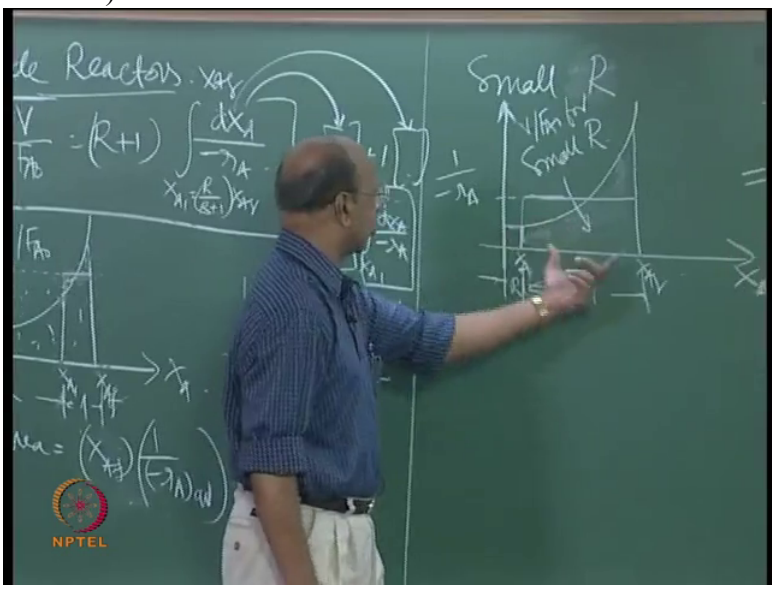

area equal to, yeah you can prove that. Again this area equal to...

Student: So the other way...

Professor: Because R is small. Do not think R is always large. It can be point naught 1.

Student: Ok

Professor: Yeah, but why do you think always yeah, what are limits of R?

Student: Ok

Student: Zero to infinity

Professor: Zero to infinity. That is point naught naught 1.So I think if I move still further then I have to have much more, you know. It comes like this, comes like this and then

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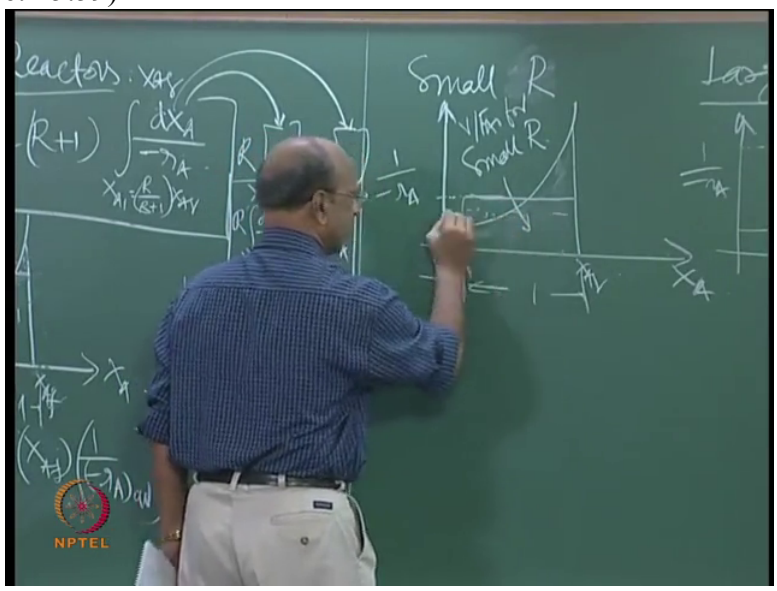

Student: It can be a rectangle, Ok it could be...

Professor: We can, we have to.

Student: Then it won't match....

Student: Then there is no point of...

Professor: Why it won't match with the equation

Student: Because Sir,

(Refer Slide Time: 26:15)

if R is 0:26:16.1, then P F R increases.

Student: It becomes lesser 0:26:21.3

Professor: yeah, still there is some R. Ok, that means still there is some product which is going and mixing

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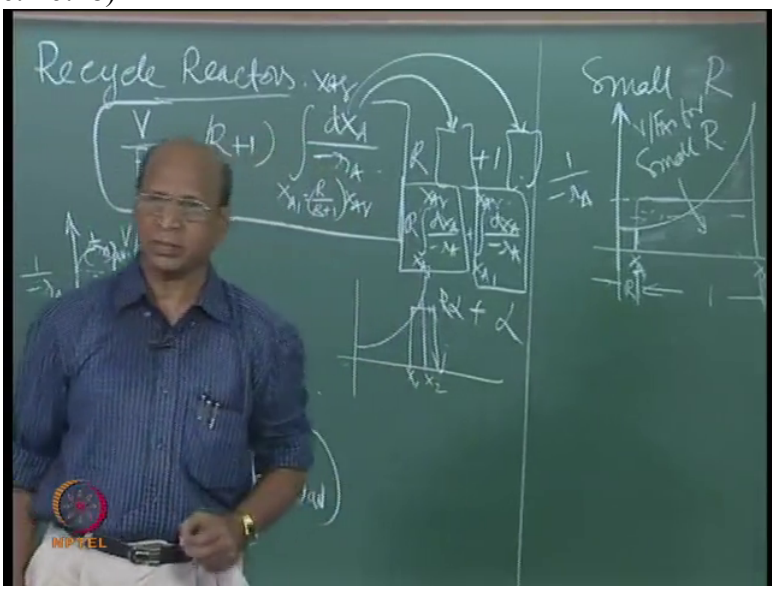

in the reactor, right? So you have only the combination of mixed flow as well as plug flow. This is correct.

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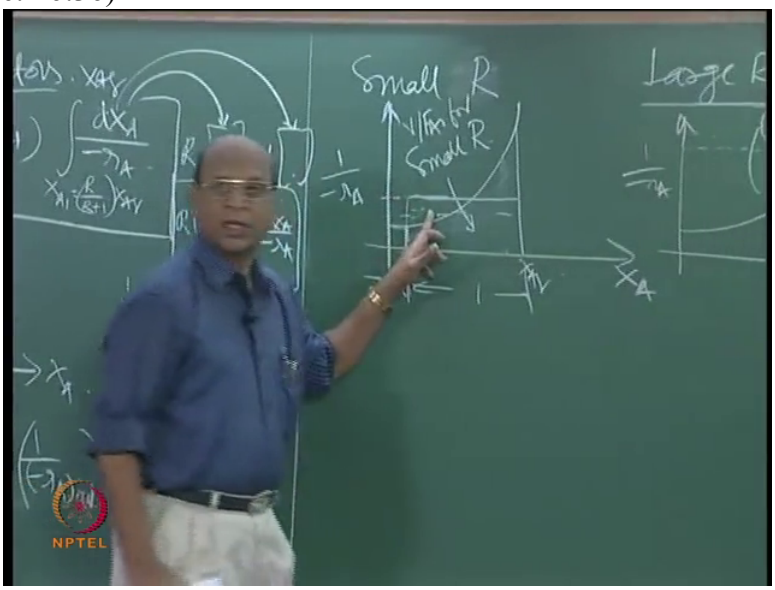

So when you are going further smaller and smaller, smaller you go next here, you go next here. You go almost till here. So entire

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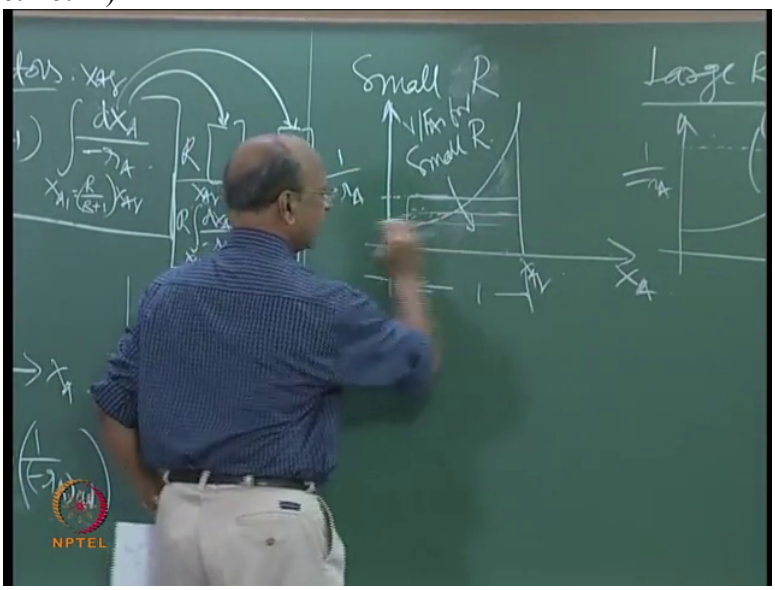

thing will come.

Student: 0:26:48.2

Professor: What do you mean by does not become a P F R? You know

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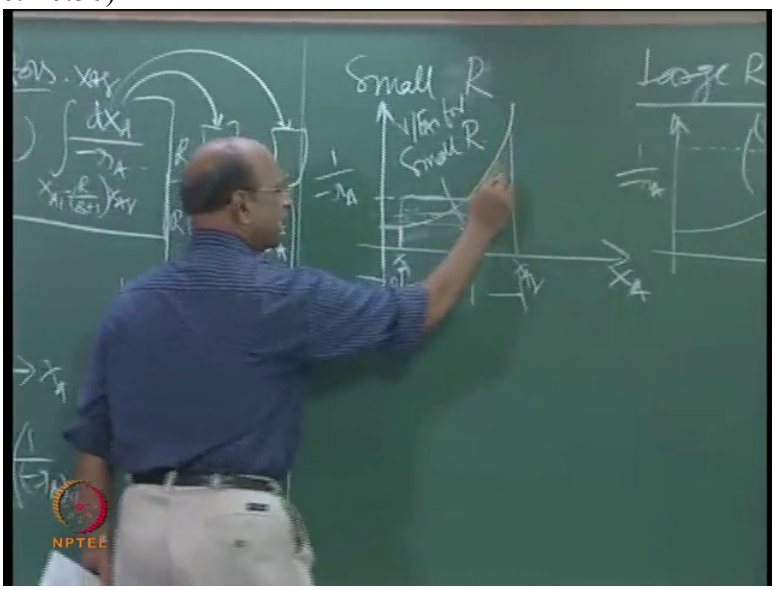

this entire area is coming. See here, this is

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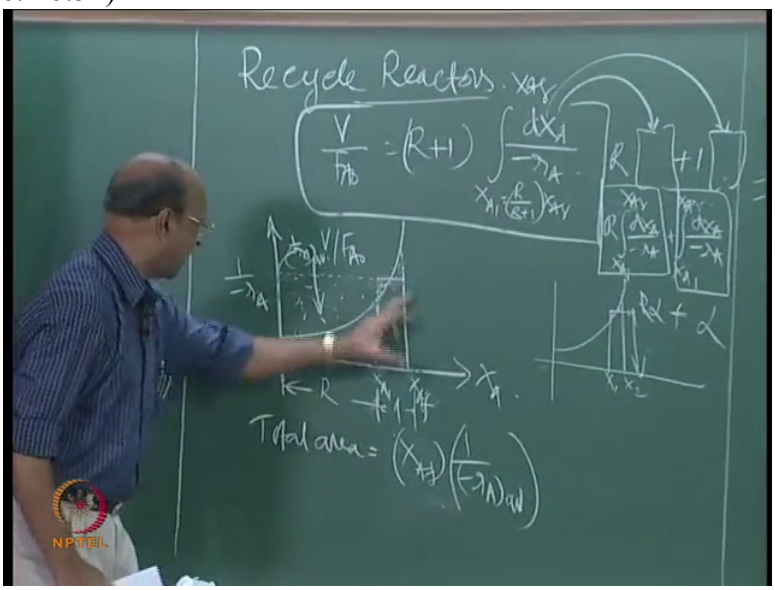

the area, this is the area. So now this is reducing, reducing, reducing and then it goes area under the curve when R equal to truly zero, when R equal to truly zero.

(Professor – student conversation ends)

And please do not think that R should have always larger value. It can be point zero zero 1, right. That means small amount only. So that is why when

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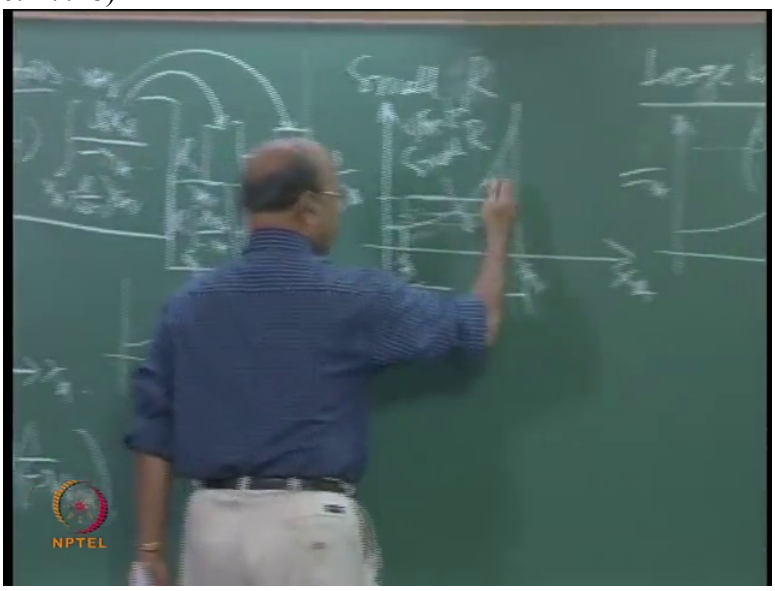

you are using this, definite I think, very good what you have asked because this also I should explain. Then it comes less, it comes less. You know.

What is here

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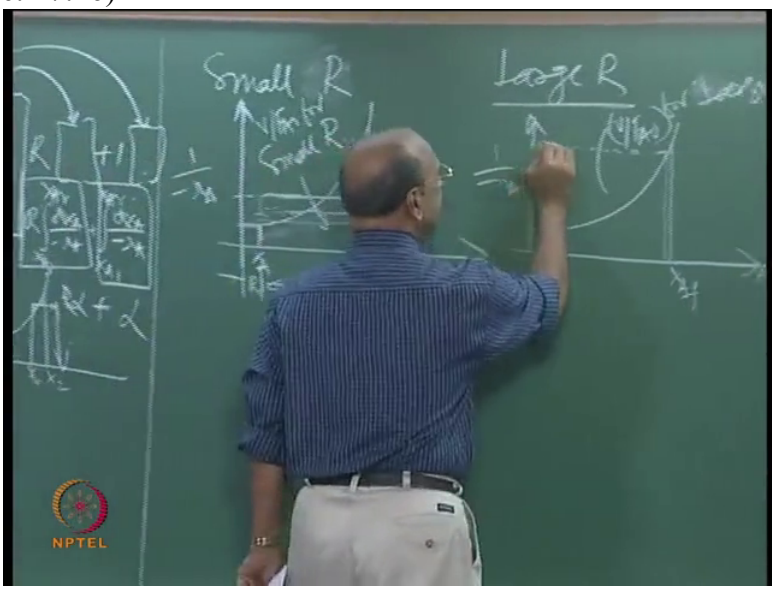

when R is large? It is almost like, you know like total rectangle. But here this rectangle area will be decreasing,

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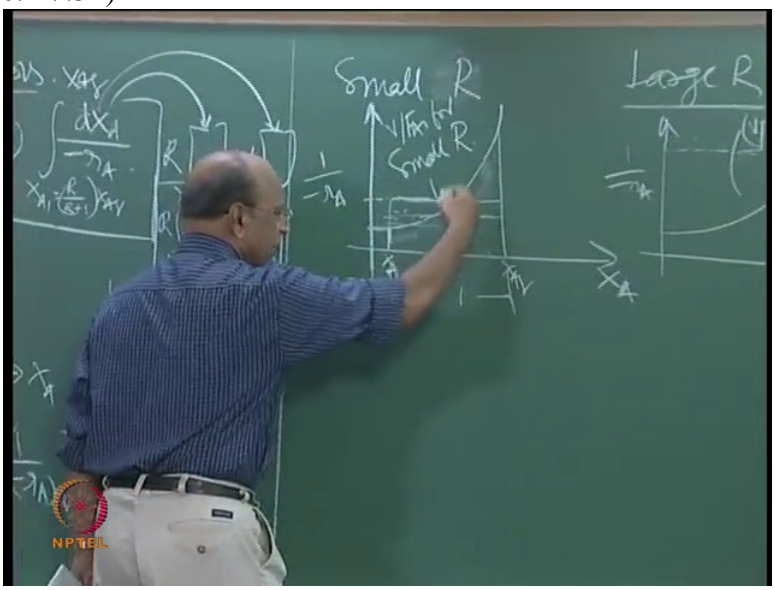

decreasing when I go to R equal to zero, right? When R equal to zero then, still further less means it will come here, Ok. Yeah. So like that slowly it goes to zero.

In fact that also depends on what kind of minus r A we have and all that. Ok, so I take till this point if it is only, you know, same thing I think 0:27:54.5 was asking. You asked no, why do not you take only area under the curve? Why we do not take only area under the curve? Avinash is asking why we cannot take only area under the curve. Even here also you could have asked me the same question. Ok. If I take only

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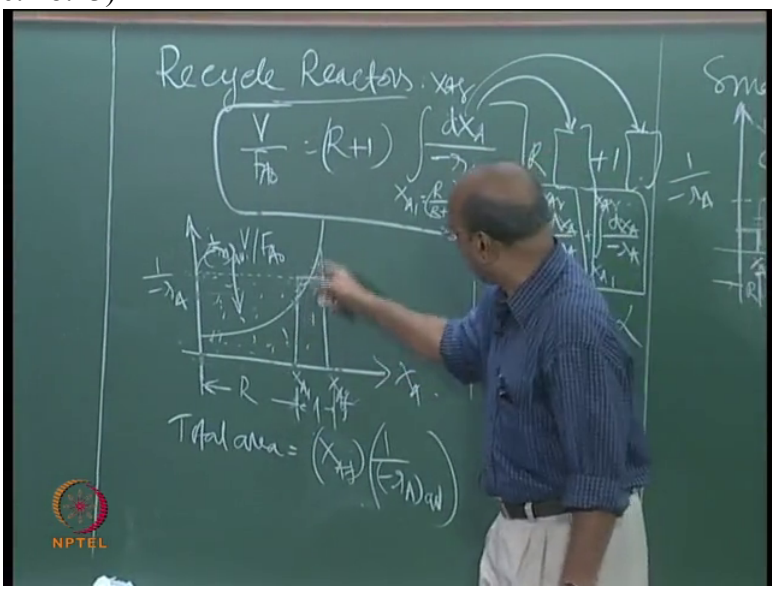

area under the curve, it is simple P F R.

(Professor – student conversation starts)

Student: 0:28:19.9

Professor: Yeah but it is not

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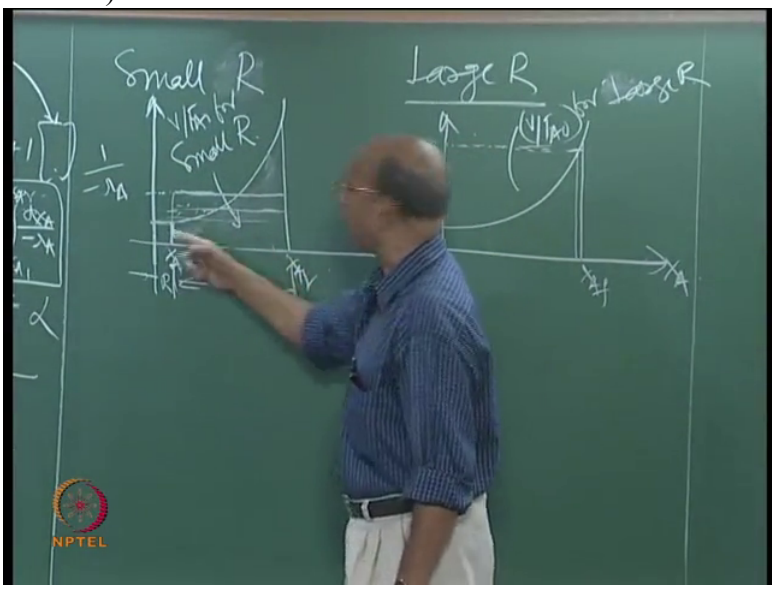

P F R.

Student: Sir, when R is very small...

Professor: Which? Yes. See

Student: 0:28:31.7

Professor: No, no. I can, I mean how can I take this one as rectangle afterwards? Because it is not P F R separate, I mean

(Refer Slide Time: 28:37)

M F R separate.

Student: It can be....0:28:40.9

Professor: See I think you are imagining that there are 2 reactors.

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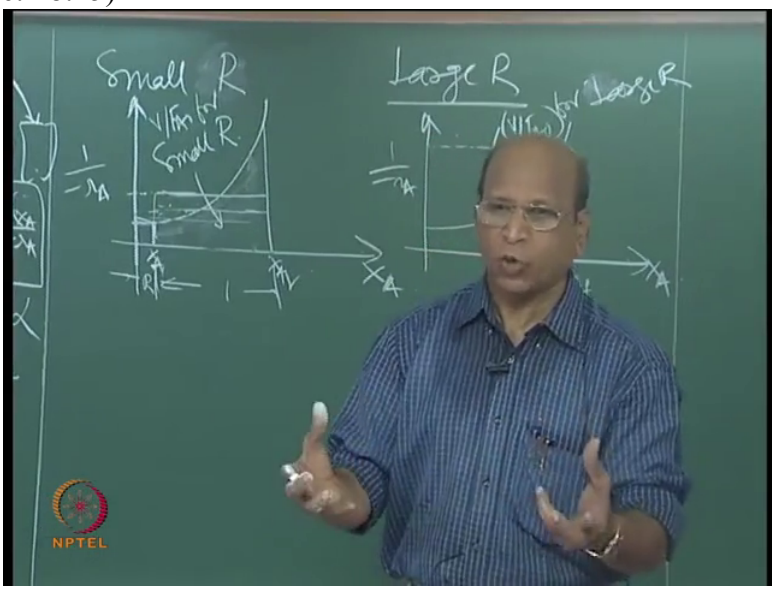

There are no two reactors. There is only one reactor.

(Professor – student conversation ends)

What he says is I will take till here,

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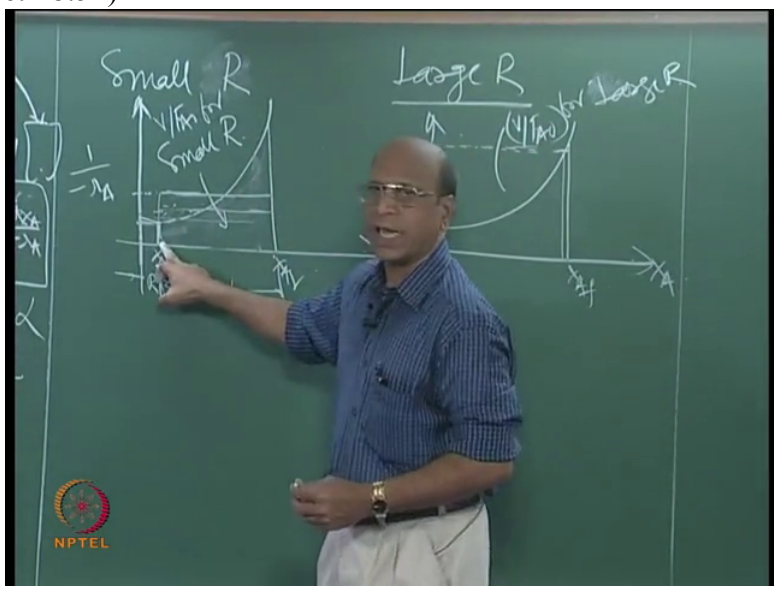

the area under the curve and from here I take rectangle. How can I take? I do not have separately mixed flow reactor and then afterwards I do not have separately a plug flow reactor. It is the combination of both.

So that is why I have to take only this average rate and then take the average area where it represents this part. Also it represents the other part.

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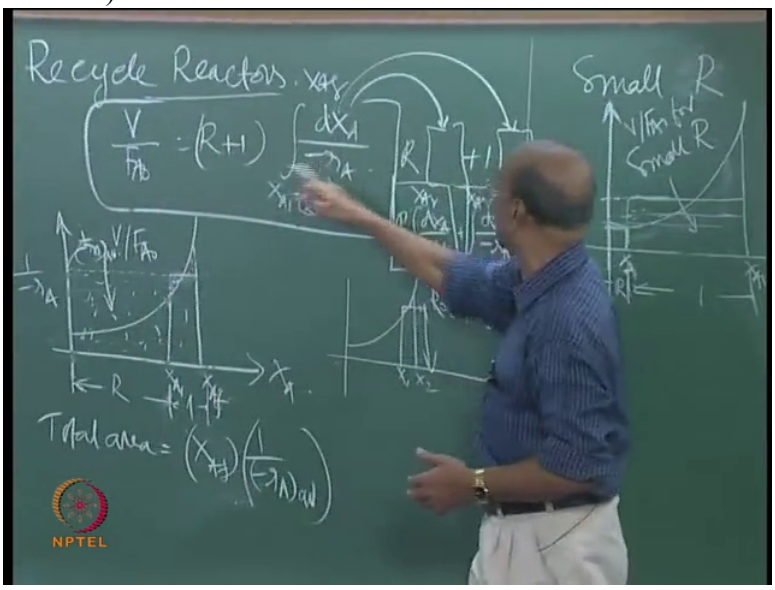

That means these two parts.

(Professor – student conversation starts)

Student: You take the average and

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obviously the values will be different. What is the point of taking average?

Professor: Why it is distorting, I say? First of all, I do not understand why it is distorting?

Student: When R is very small...

Professor: This is one method where

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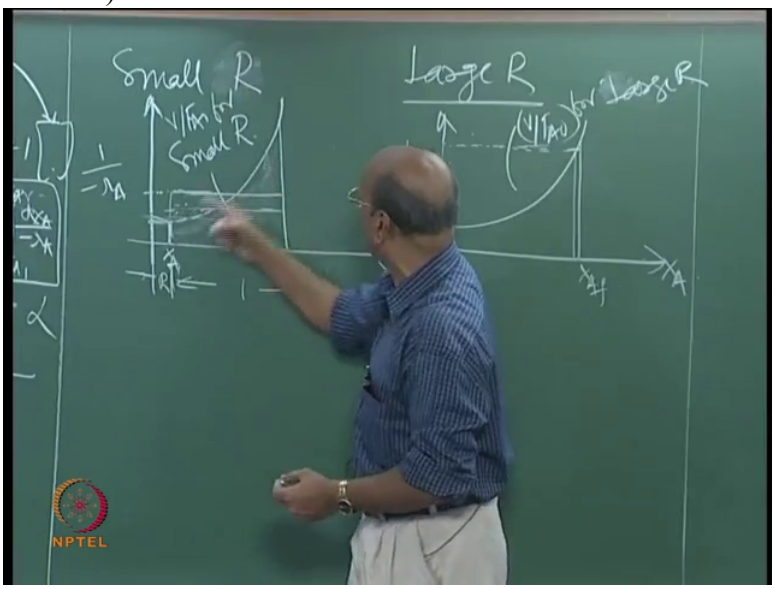

I know; I can average this and then make the entire thing as the rate so that this entire thing will give that equation V by F A naught. Yeah

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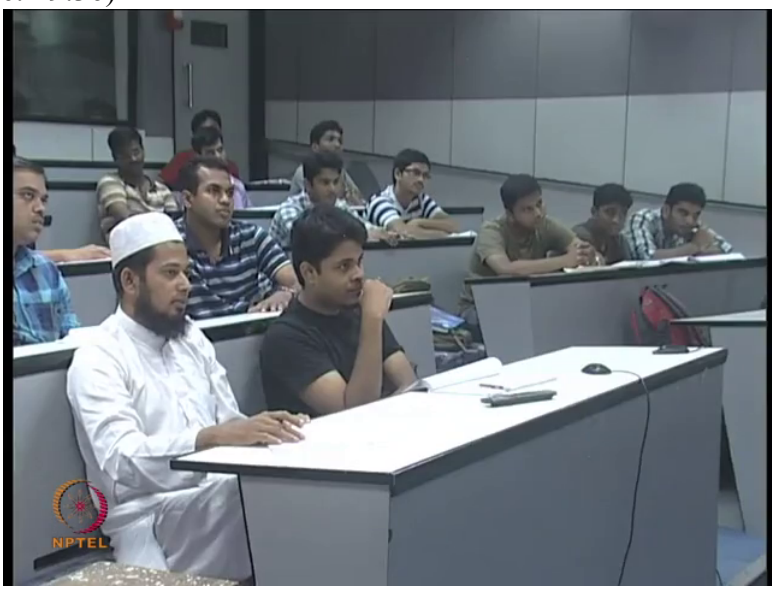

and if it is small, if you are not losing much area, take area under the curve. If it is so small.

(Professor – student conversation ends)

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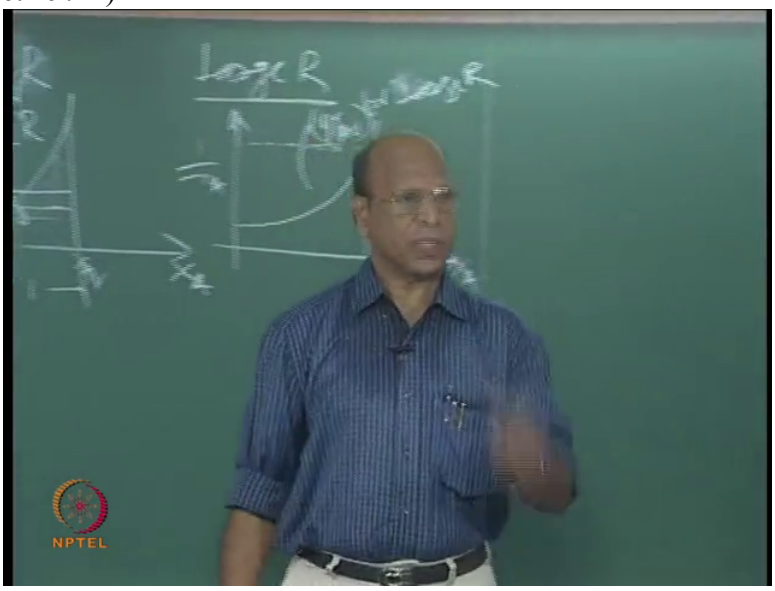

That means you are only approximating. You are not actually solving the V by F A naught. Ok, you are only saying that even if I take this, there may not be much change in the area, so I am taking that, that is all.

Even this, when you are doing this, why you are doing? Essentially you are taking this entire area. Correct, no? Even this entire area only I am taking even if I am drawing this. Correct no? But only thing is instead of taking area under the curve like this, I am taking this equal to this and making as a rectangle.

So when R is becoming smaller and smaller, that comes only area under the curve. Almost when it is touching zero, definitely it is area under the curve. That is plug flow reactor and this is mixed flow because

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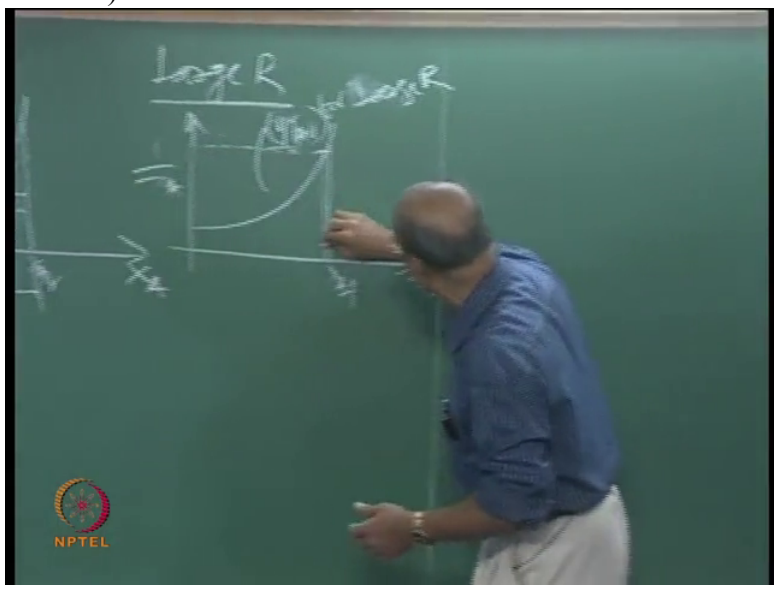

this side when you are moving and you know this area is getting smaller and smaller, so in the limit this becomes only one value, and that is the total value, that is V by F A naught, when R equal to infinity.

That one component is zero that means this is; yeah you can also imagine it in a different way. This is plug flow component

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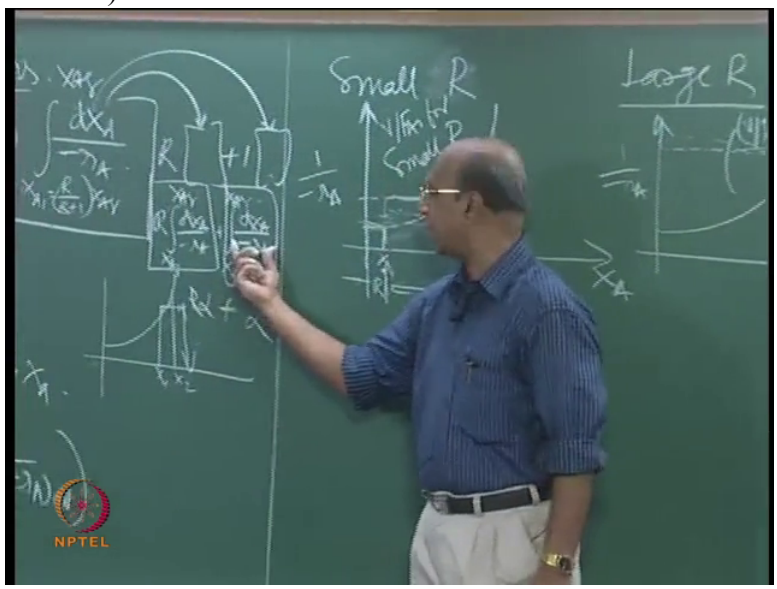

and this is mixed flow component. Do not think this is mixed flow reactor, this is plug flow reactor. Ok. This entire design expression because of intermediate mixing has two components.

One is R component you know which represents mixing. And one is this component which represents plug flow. When, when R is very, very large then plug flow component becomes very small. So that is why area under the curve will be rectangular area, yeah, Ok this entire area, rectangular area, when R equal to very large. Correct no?

Yeah when R equal to very small, that means this part will become zero,

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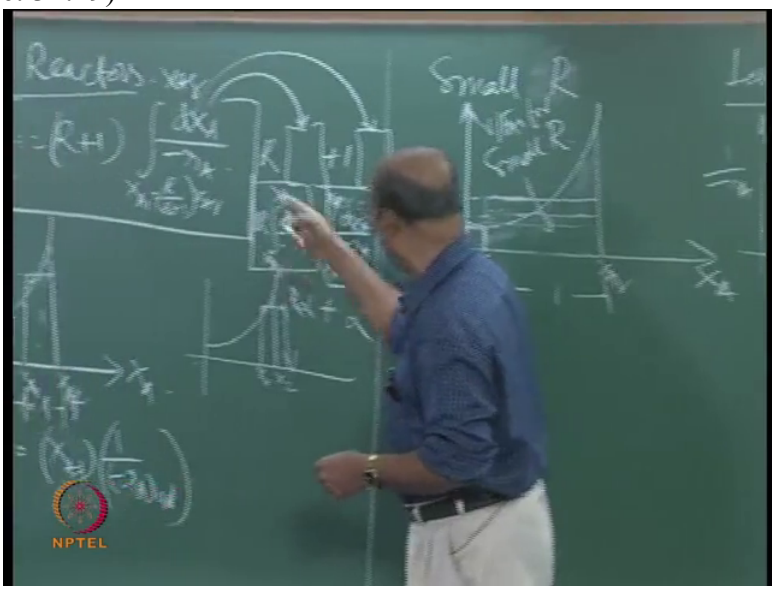

very small that is why you know this part

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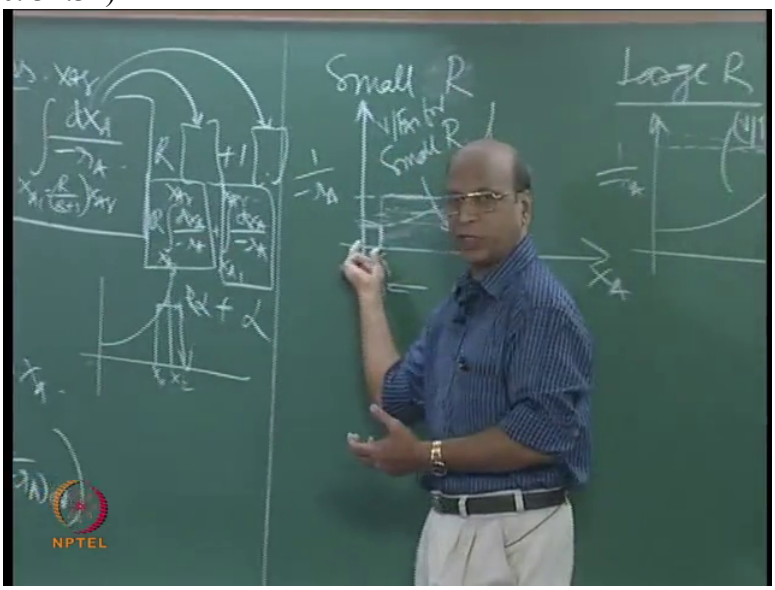

is very, very small and the rest, the other part is the area. So that is why these two components, please remember.

That equation; that is why you know writing book is very easy. You do not have to explain so much. Because you read and then after you do not read, if you do not understand, Ok close the book. That is all. Ok. But here, explaining. Definitely I will be happy to explain that.
This

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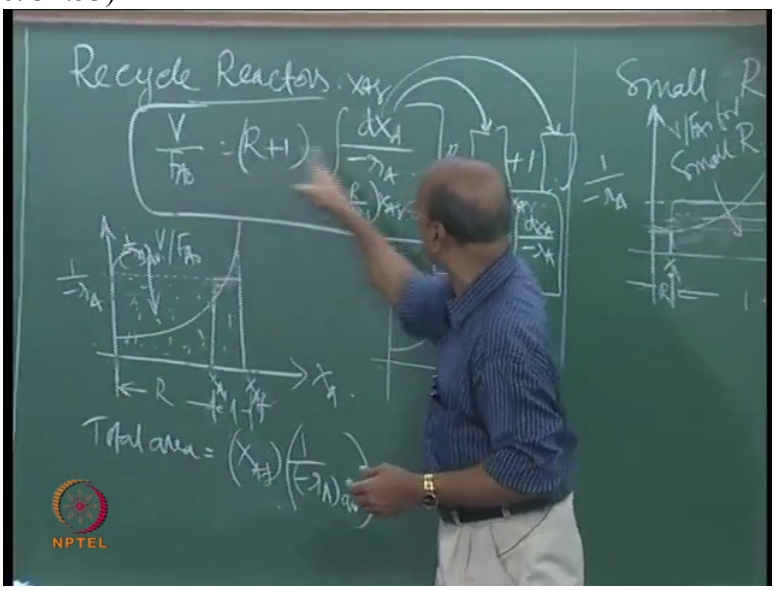

entire recycle reactor has two components within one reactor, right. We have the plug flow component as well as mixed flow component and that is reflecting very easily in this equation. When R is larger then plug flow component will be smaller, right?

What is happening when R is very large? You are taking almost all that that is reacted, small amount you are taking, you know this is another thing where you have to imagine that. What do you mean by R equal to infinity? This is R, so this is F A naught, this is F A f, X A f, Ok. So this is X A naught equal to zero. So what

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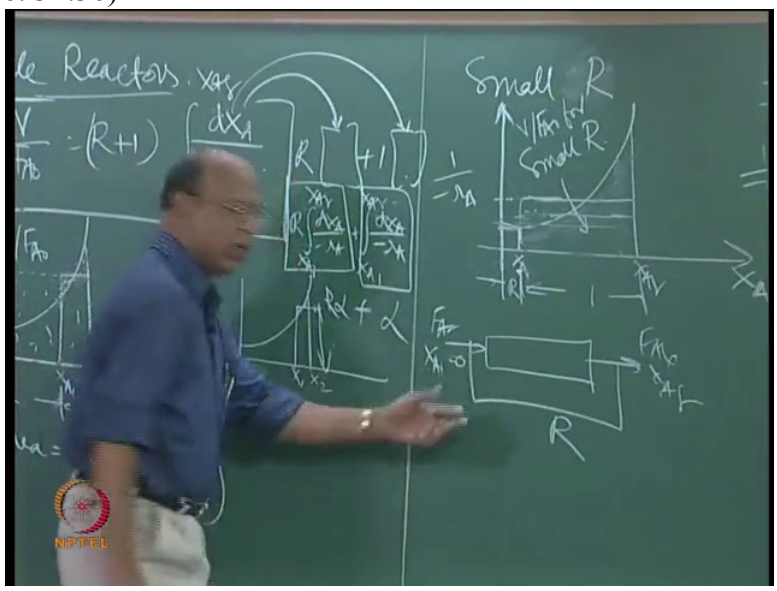

is the meaning of r A equal to infinity?

(Professor – student conversation starts)

Student: 0:32:43.0

Professor: No, but how do you really maintain that? It is still a reactor. It is a steady state reactor.

Student: Sir, complete mixing is there.

Professor: Yeah, that is not correct actually. It is not, no output. If there is no output, what will happen, I say? If you do not have outlet and you keep on eating?

Student: (laugh)

Professor: What will happen? Stomach will burst. Exactly, that is good answer. It will burst. Right no output, only input.

Student: No input...

Professor: So that is why if I say that R equal to infinity means there is no, nothing is coming out but I am putting this means how? I mean that is not a steady state reactor. So that is the reason why I asked that question, right? Meaning is that when I take

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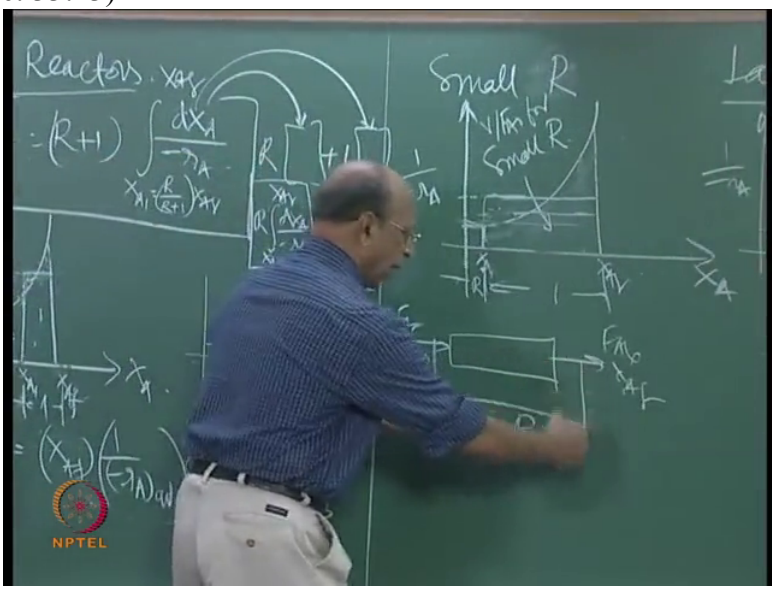

1 meter cube, 1 meter cubed contains how many centimeter

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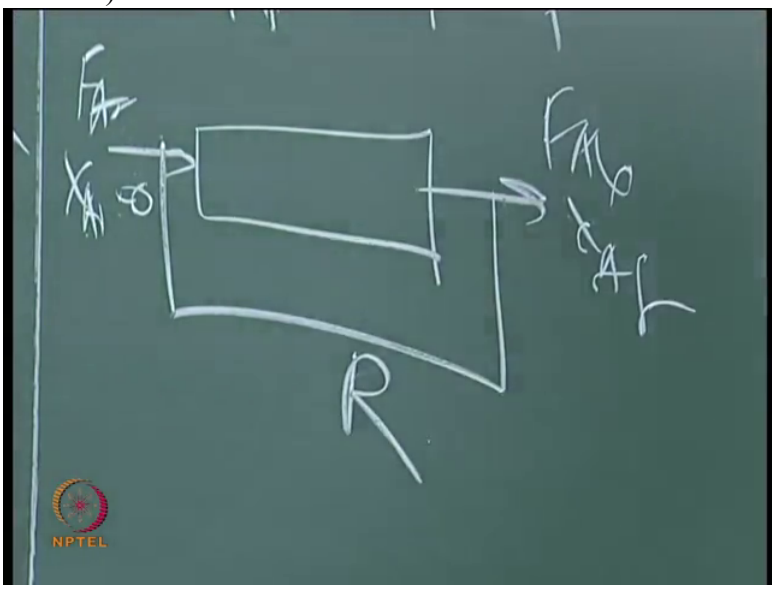

cubed?

Student: 10 raised to 6

Professor: 10 to the power of 6, Ok, 10 to the power of 6 m l I am recycling and only 1 m l enters here and 1 m l goes out.

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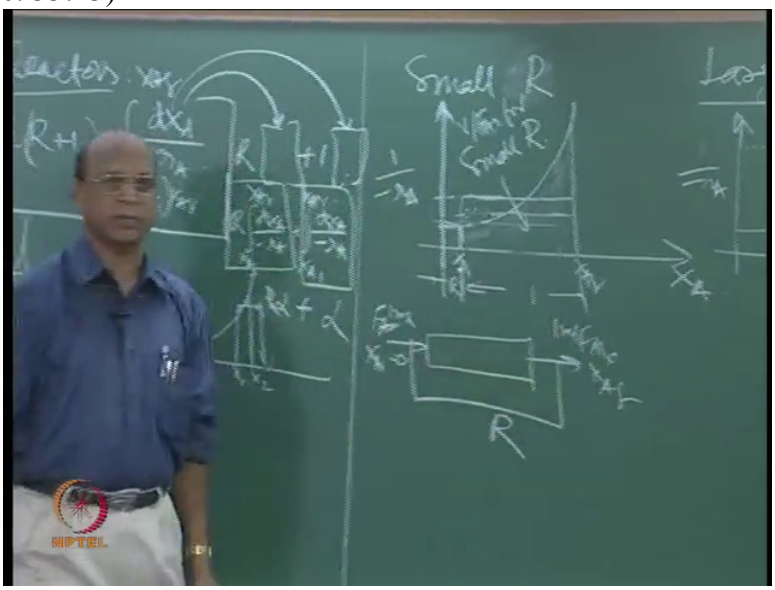

It is still steady state reactor. Only 1 m l going out, and 1 m l, that means now how do I define my recycle ratio?

Student: Ratio to the amount withdrawn

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Student: Amount recycled to the

Professor: Yeah. Amount recycled to amount withdrawn.

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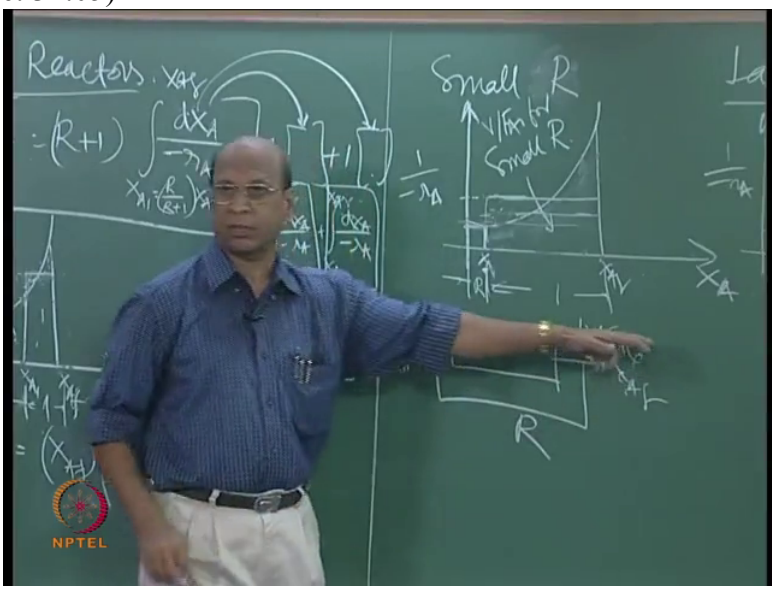

So I am now 10 to the power of 6 m l I am recycling back and then

Student: 1 m l

Professor: 1 m l I am just putting in. Ok. Then what is happening in the reactor if you physically look at that? What will be the concentration? What will be the concentration here, here, here, here, here, here, everywhere?

Student: Same

Professor: Then if you have concentration throughout the reactor uniform what do you call it?

Student: Mixed flow reactor.

Professor: That you should think, I should not have to tell.

(Refer Slide Time: 34:33)

Really. That is the reason why when you say R equal to infinity means then you will have mixed flow reactor. Meaning is that.

It is not that R equal to infinity

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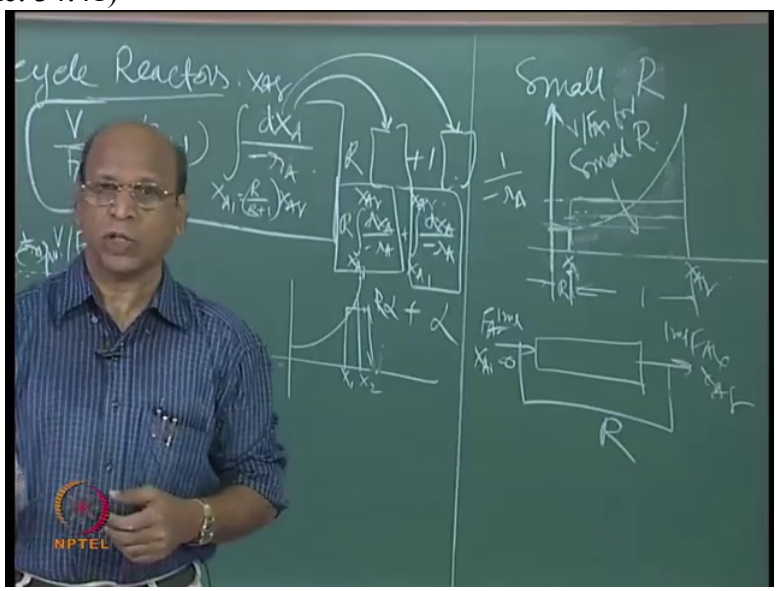

means everything is taken out and then you are recycling. Then it keeps on, because you are feeding anyway. Nothing is going out. And then you keep on recycling, what will happen to the reactor? Burst.

(Professor – student conversation ends)

That is why there is output, there is input. But the amount of input that is coming is 1 m l and 1 m l per second is coming out or per minute is coming out but I am now recycling 10 to the power of 6 m l, that means 1 meter cubed of thing is recycled.

That means practically whatever is happening inside is like mixed flow where after all the conversion I will take it and again put it back. Conversion, take it. Steady state, there is only one conversion. Ok. That is the reason why everywhere I do not see much change in the conversion. Everywhere. Throughout we have only one conversion. So that is nothing but your mixed flow reactor. That is what R equal to infinity.

R equal to zero is very easy to imagine, right? When R equal to zero, this stream is not there at all. So then even 1 m l is coming out, one m l is going out. But there is change between this place to this place and if I plot X A versus z, conversion increases.

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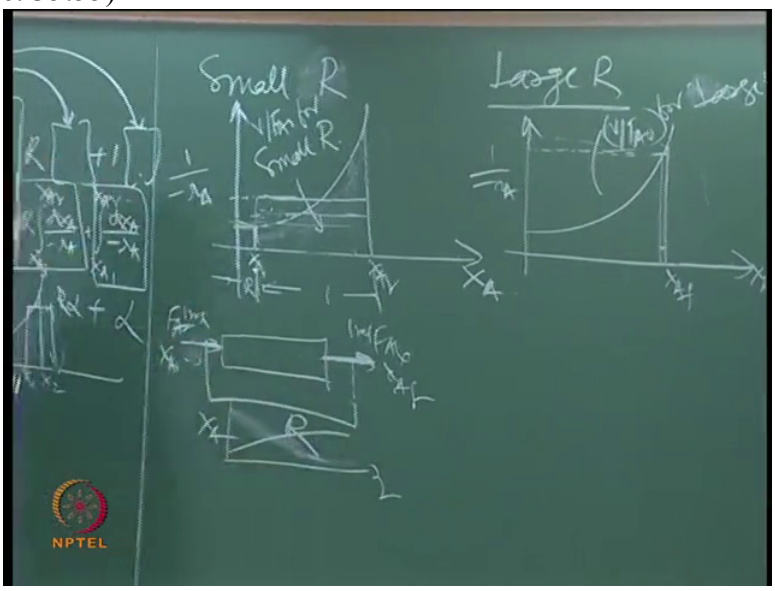

Ok. This is R equal to zero.

When R equal to infinity, how do I plot? X A versus z? That is all, constant.

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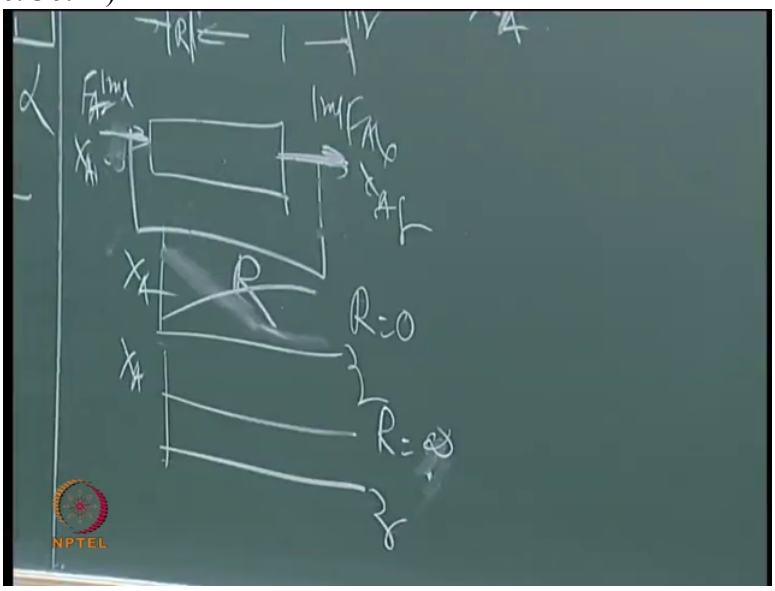

So throughout the reactor, we are talking about the reactor, please do not again get confused. We are talking about reactor where this is almost horizontal because we are taking so much back and then putting it, practically inside there is no reaction, in the sense that small amount is coming, mixing and then getting reacted, that small portion and then we are recycling back mostly.

So that is why when R equal to infinity you will get mixed flow because of this reason, because everywhere inside the reactor I do not find much change in the concentration, temperature and also conversion. When there is no concentration change conversion also is throughout, so that is the reason. Ok, good. So this is the one. And then hope it is clear now. This V by

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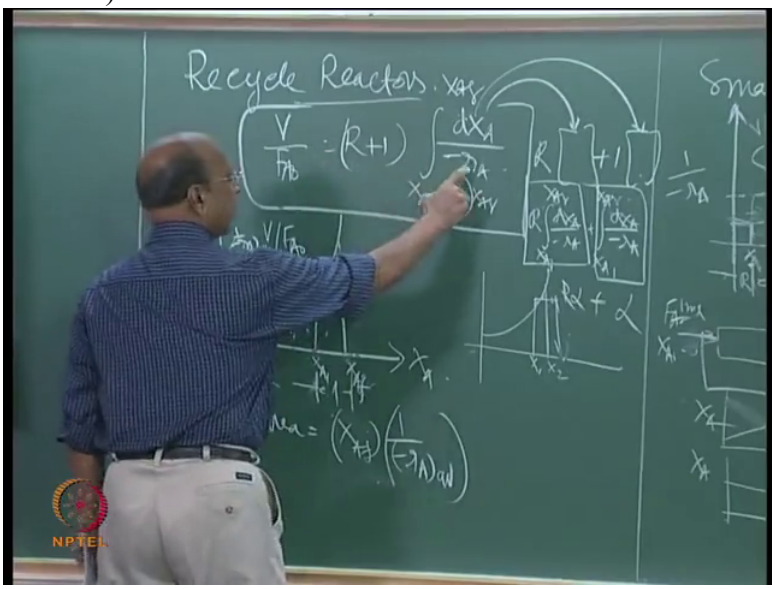

F A naught minus r A if I have a first order reaction, then what you have to do is for first order? One second, I think V by F A naught equal to R plus 1, yeah X A 1 I will write which is nothing but R by R plus 1 X A f, X A f d X A, first order only, no volume change. Epsilon equal to zero. Epsilon A equal to zero.

So what is the equation I have to write here? k into C A naught into 1 minus X A.

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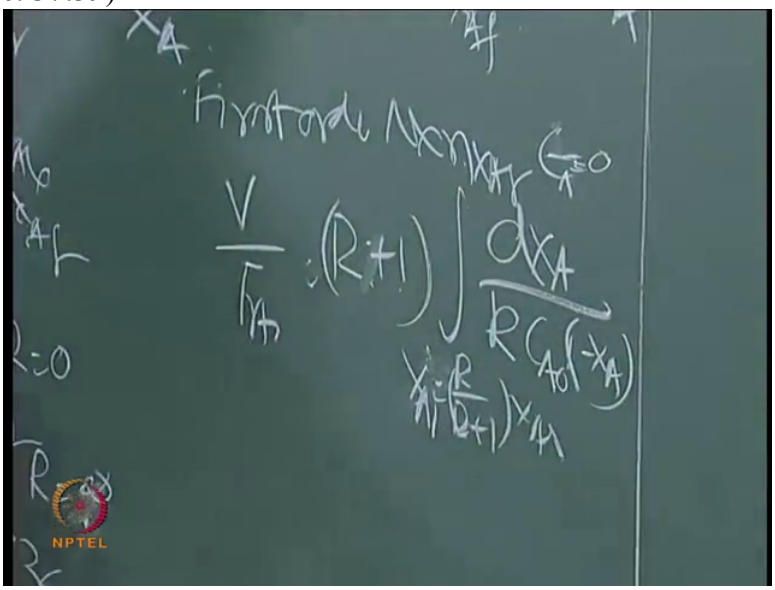

So this you have to integrate. Right and then substitute the proper limits. Do not put zero to X A f, proper limits. So then what you get here is, if I write in terms of k tau for easy writing, k tau equal to R plus 1, in terms of conversion this will be l n 1 plus R into 1 minus X A f divided by, R plus 1 into 1 minus X A f.

Please remember. 1 plus R into 1 minus 1 minus X A f; this is R plus 1 into 1 minus yeah.

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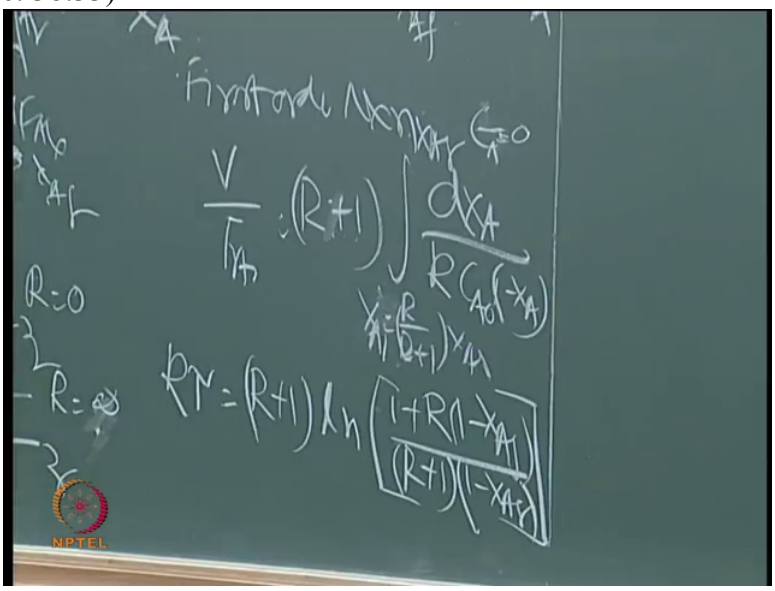

So like that for second order reversible reactions, all these things you have epsilon change. All that you have. So that equation can be used equally well for epsilon there, epsilon not there. But only thing is mathematics are complicated unless you really solve 1 or 2 problems, actually integration you cannot do it in the examination. Ok, good.

I think I will stop here and Levenspiel has very nice derivations and all that in the book. Levenspiel only gave this kind of nice diagrams. They may be confusing, that is why many teachers may not tell you also about this. Ok, yes? No explanation. Even in Levenspiel there is no explanation. I think you know how much time we have spent now;

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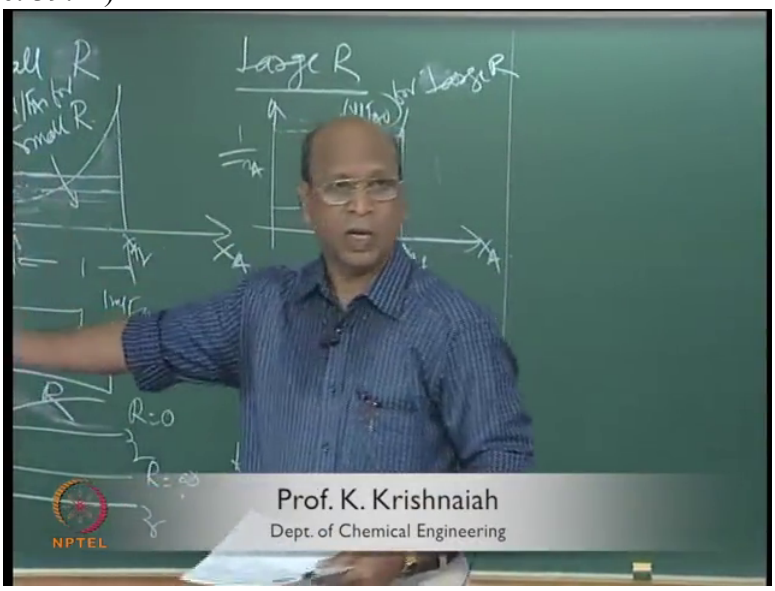

I think hopefully at least for some people, it is clear.

I do not think everyone have that clarity unless they think and also unless they also discuss with others. You have not followed, still ask me. Ok. good. Ok you carry on.