Chemical Reaction Engineering 1 (Homogeneous Reactors)
Professor R. Krishnaiah
Department of Chemical Engineering
Indian Institute of Technology Madras
Lecture No 30
Recycle Reactors (Autocatalytic reactions) Part 1

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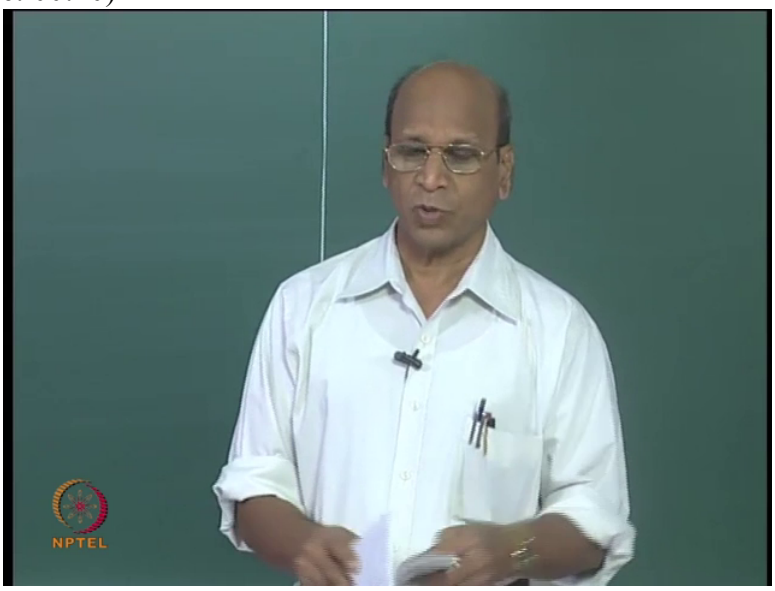

So yesterday, what did you do about recycle reactor?

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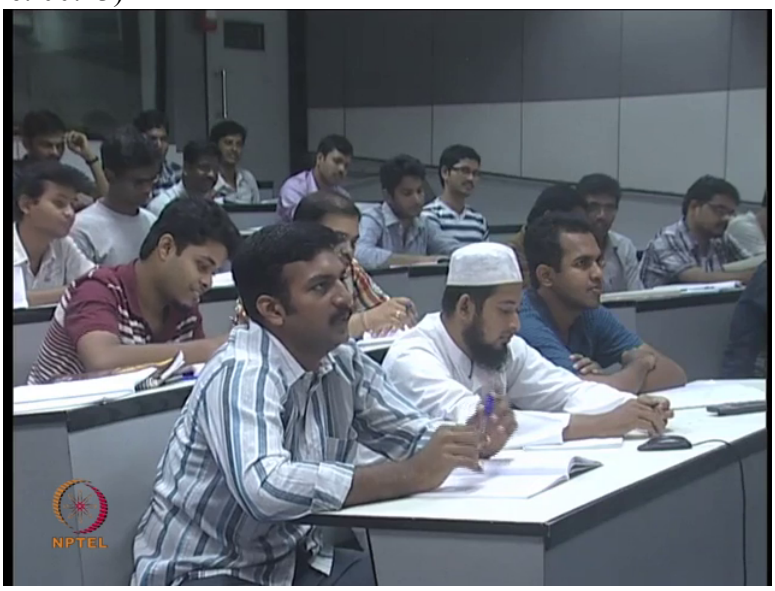

(Professor – student conversation starts)

Student: Smaller and...

Professor: Smaller and larger. I think, still you understood that no? Smaller and larger

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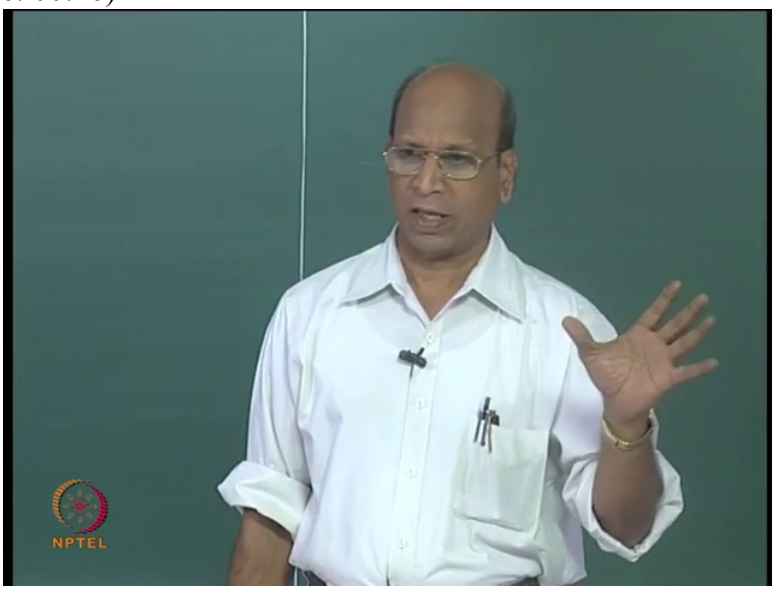

why it comes? Yeah. But the other areas, anyone proved? Anupriya you got it. Excellent. Very good, one person. You have done, Abhishek? Yeah, good, Ok, 2 people at least. Good, Ok.

(Professor – student conversation ends)

So we will now go to autocatalytic reactions. Yeah, I tell you there are lot of equations that we have to derive for recycle reactor, for first order, second order, second order with epsilon and all that, and the reversible also. Reversible also, A going to R, reversible reaction, all these things, it is only mathematical exercise.

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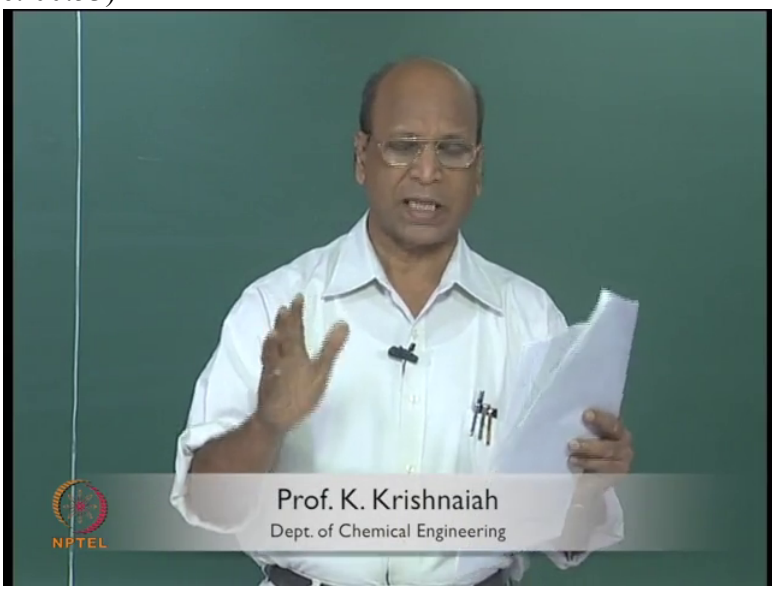

So that is why those mathematical exercises you have to do on your own. If you are not still believing then you know I cannot conduct 100 tests, no. Only maximum 3 or 4 we thought.

First only 3 we will say first. Afterwards we will see, depending on...If you are writing very well, why 4, all of you? For one person I cannot. Ok.

There will be always one person who has not done well. For that one person alone I cannot conduct test 1, test 2, test 3, test 4 and all that. On the average if all of you have not done well then we will conduct another test. Ok, that is not a problem. So that is why these mathematics are very important, those derivations.

So now let us take autocatalytical reactions recycle reactor. Yeah,

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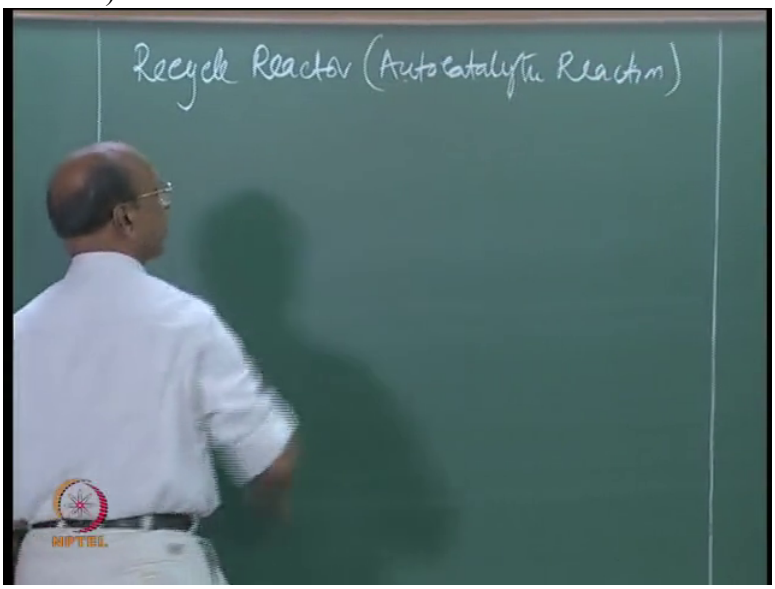

Ok, recycle reactor autocatalytic reaction that means you know why recycle reactor is better for autocatalytic reaction. But till now we have not discussed about autocatalytic reaction. Let us discuss also about autocatalytic reaction.

By name we know

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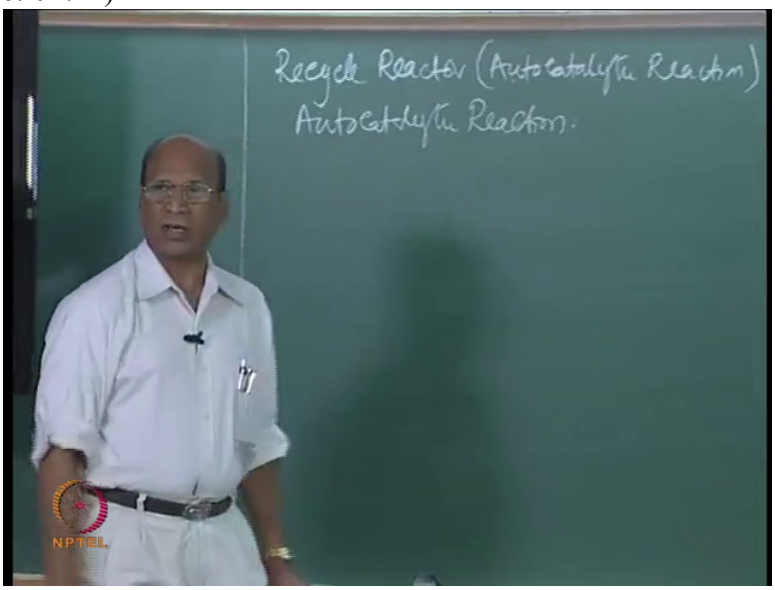

that autocatalytic reaction means the product would have catalyzed the reaction, Ok. So the general scheme that is normally written for catalytic reaction or, yeah, R is the product. That is for the balance, Ok. So if that is not there, then it is not autocatalytic reaction. Because R

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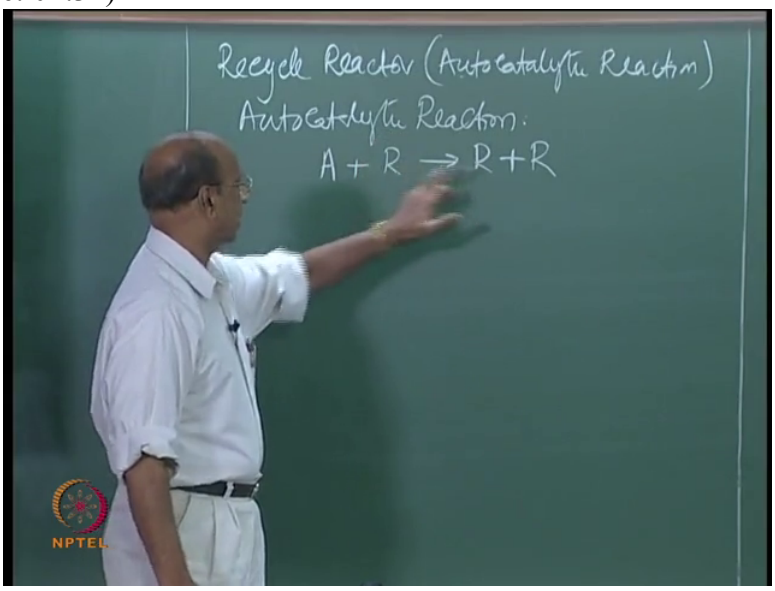

is again participating and you know the reaction takes place because of that. And if it is irreversible, I can write this one as C A C R, Ok.

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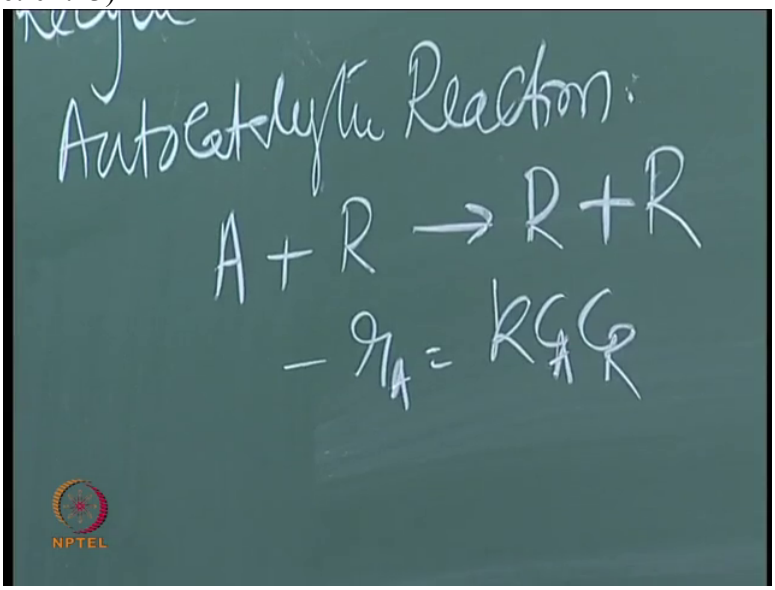

And there are also many equations, many reactions that are available in particularly organic chemistry where some names also, some of them I will give you later, right, so this reaction is possible so now we would like to find out whether which reactor is the best for this. So before that we should also have an idea what kind of rate versus conversion graph we get.

So from this rate what we can first discuss is that initially this is C A naught

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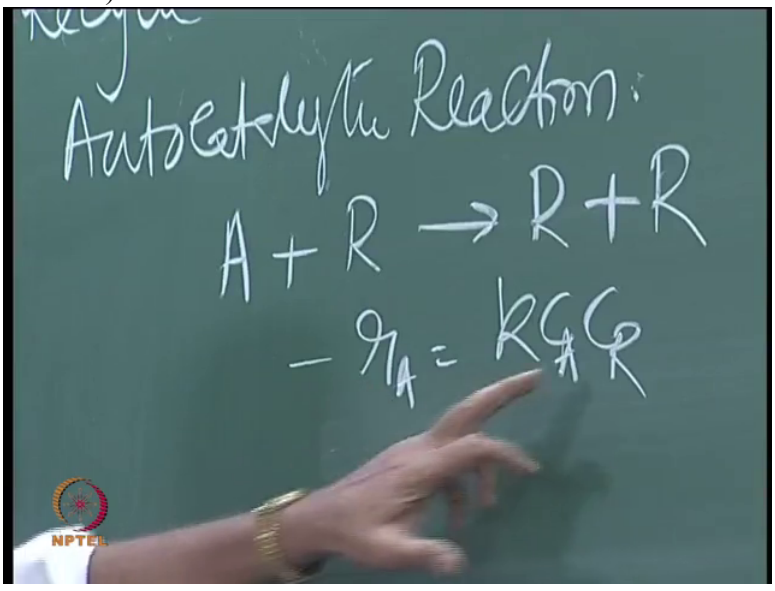

to start with. And there may be very small amount of product that would have formed, very small amount, Ok. So then that small amount is represented by C R.

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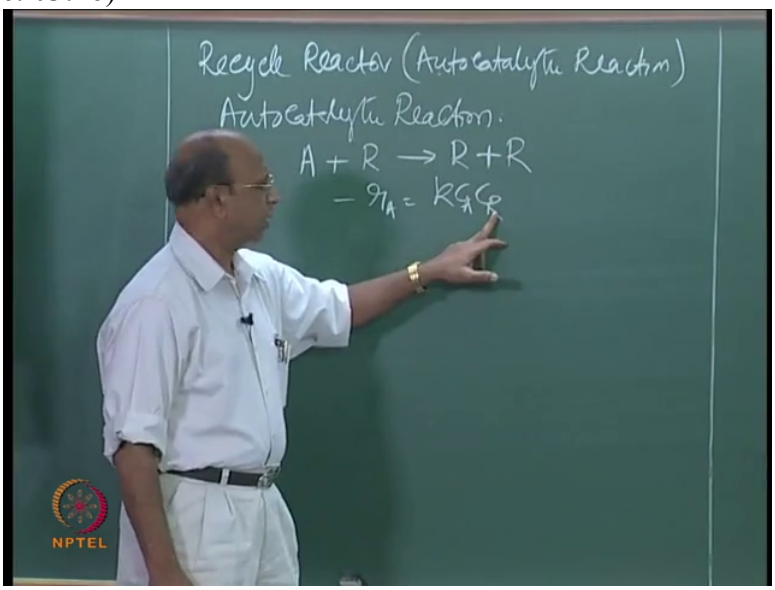

To give a value, this C R may be point naught naught 1. And C A naught may be 10 for example. So when you multiply that, then k is constant for a given volume, then R is smaller. Then as the reaction is proceeding, R is falling; I mean R is increasing more and more. And C A is decreasing also, along with the reaction, right?

So that is why this product will first go, start with lower value, then go on increasing, then reaches a maximum where C A and C R values are sufficiently large and the product is larger. Then afterwards C R will be increasing but C A will be decreasing and finally it may go to point naught naught naught naught 1, so that it will again, rate will be decreasing.

So that is why if I plot minus r A versus C A, other things also I will tell you, ask you, this is rate versus time, these two. Ok, first tell me this one, how does this look like?

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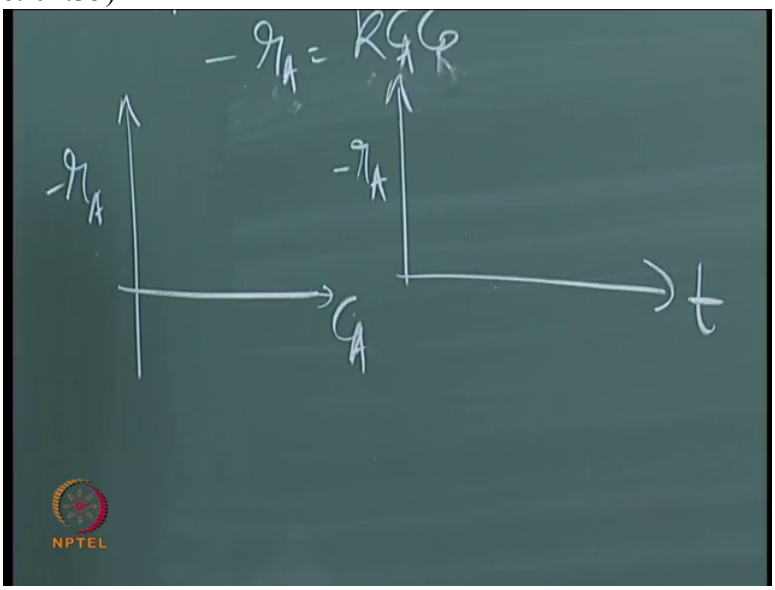

(Professor – student conversation starts)

Student: 0:04:35.1

Professor: Yeah initially it may be, because this side or this side I have to plot?

Student: This side, right side.

Professor: This side, why because this is C A naught. Ok. That side C A naught. Then it may like this. And finally it may go to zero also.

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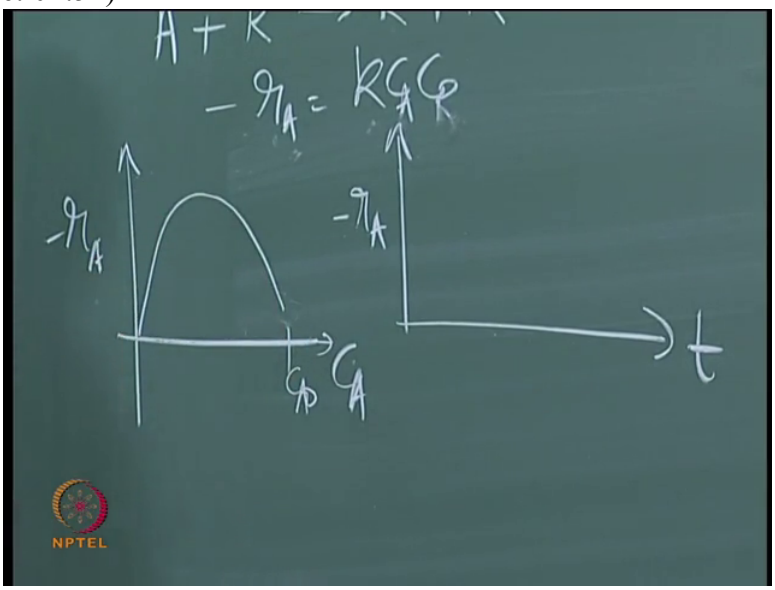

Because when C A equal to zero, C A equal to zero, so that product will be zero. So the direction we can show like this. With time how does it look like? Same parabola?

Student: Left to right

Professor: Yeah, so at time t equal to zero I may have some reaction because I have some C R left, otherwise it will never react. Ok, some C R is there. So it may start and then go to, like

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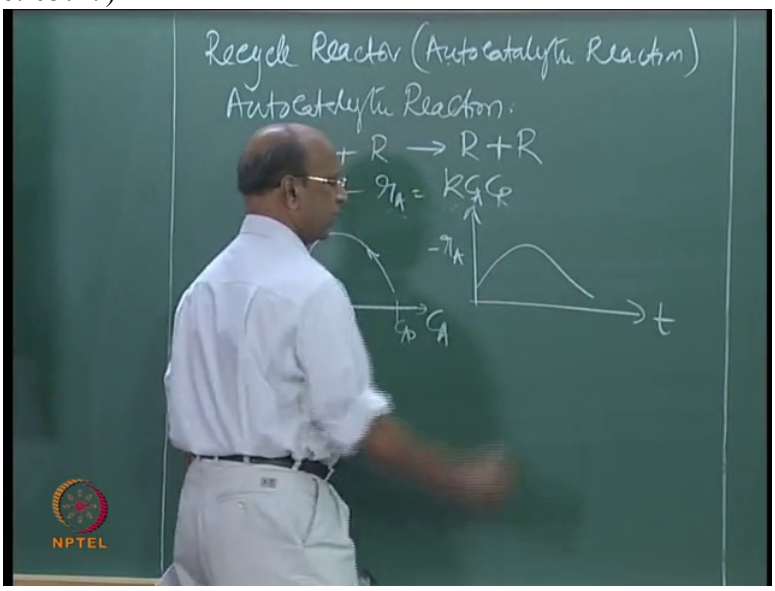

this it may go to. Ok. So this is the one.

(Professor – student conversation ends)

Ok, yeah so it seems in nature, it is also found that you may start with A,

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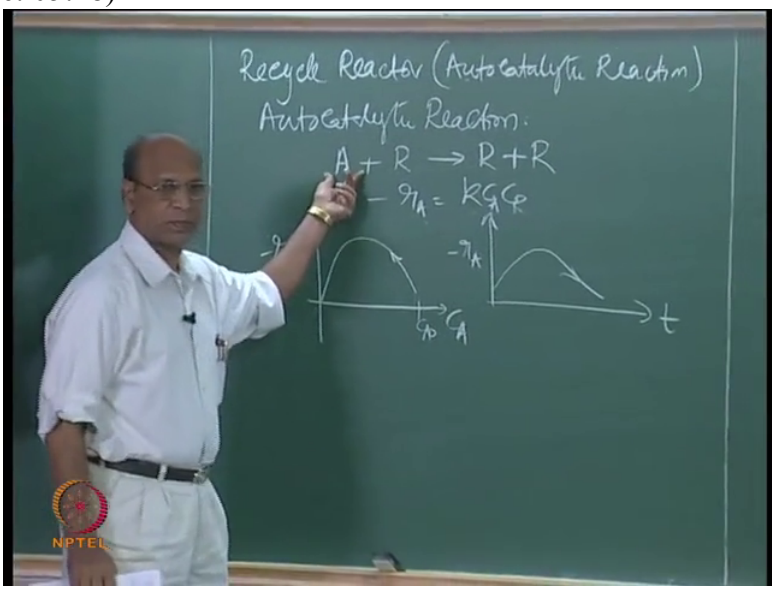

there is no product. We are not adding any product there. And on its own, there is a route where a little bit of R is formed. And then that R once it is formed, then it starts again autocatalytic. Ok.

So anyway, different schemes are there. But what we think is that anyway, whether we have R in the beginning or later, our reaction starts only when we have sufficient amount of R which has now started catalyzing the reaction, good Ok. And if I want to plot this as 1 by minus r A versus X A, 1 by minus r A versus X A, now tell me how do I, S shape?

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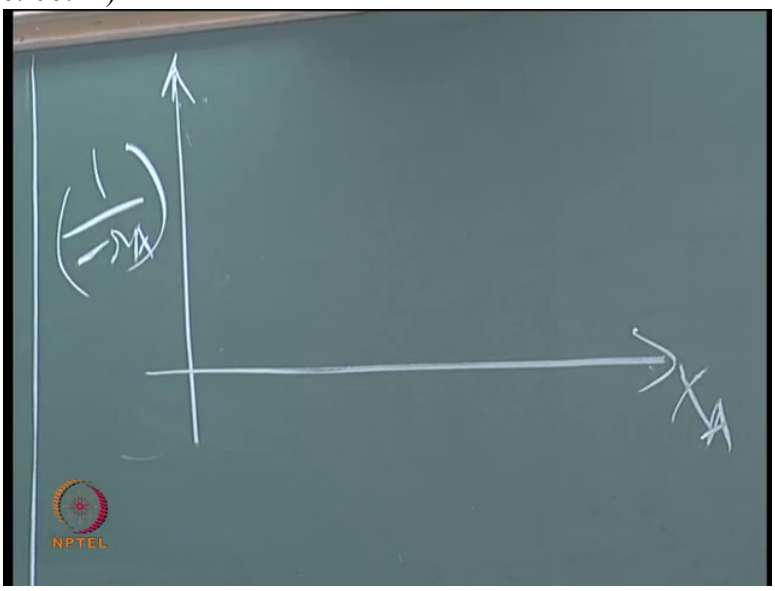

Yeah. Pooja says like this.

(Professor – student conversation starts)

Student: U Shape

Professor: Debian says like this, S shape. Yeah, any other shape? There are infinite shapes. Yeah which is right? Why did you say

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S? You saw in the book. Which book is that? Levenspiel? Do not blame Levenspiel, I say. Poor fellow (laugh).

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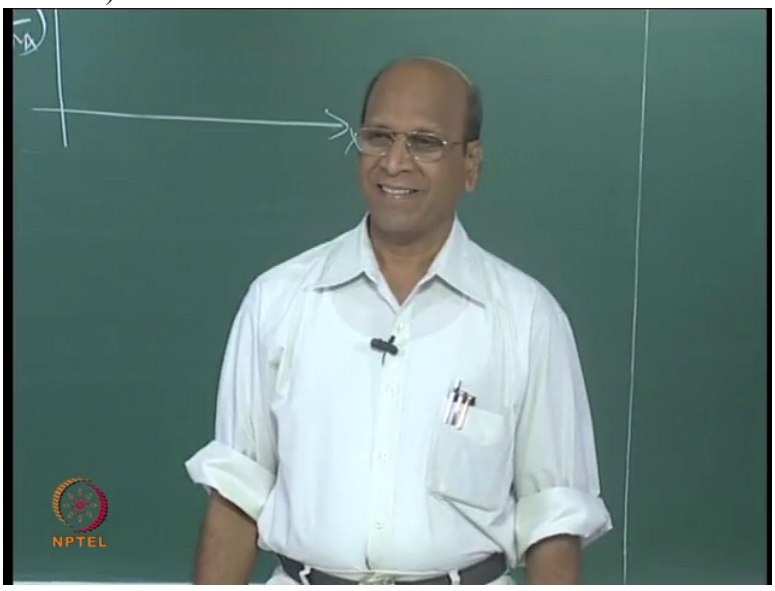

Yeah Pooja why did you say this way? You have to explain, no. Otherwise simply you cannot say.

Student: 0:06:42.1

Professor: But this is C A, this is X A no? That is why this is X A that is CA;

Student: No but starting will be left, C A X A

Professor: Starting will be left but what will be the shape?

Student: 0:06:59.3 this is going

Professor: Ok it also goes like this but it need not be symmetrical. That depends on stoichiometry and all that.

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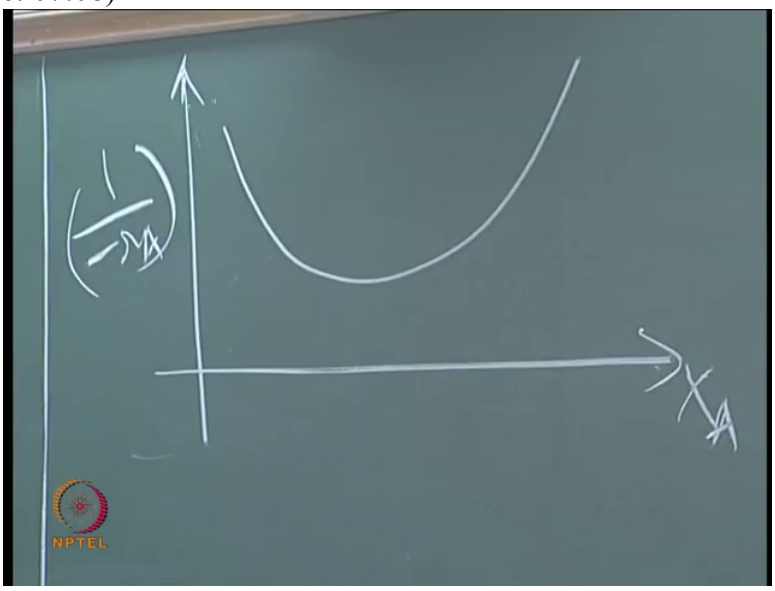

It need not be symmetrical. Ok. But under some conditions you will also get very symmetric curve, good. So this is the one. No when I have this kind of 1 by minus r A versus X A, which reactor is the best?

Student: Sir depending on

Professor: Which reactor is the best?

Student: Depending on

Professor: Because you know this. I know I tell you, I also told you earlier, that you do not have to learn anything new great concept now onwards. It is only delta x here and there, right.

(Professor – student conversation ends)

So I think whatever you are supposed to learn in C R E, you have already learnt basic concepts. But those things only, whether you are combining or subtracting, you know the concepts and finally you have to solve the problem. That is all what we have. Anupriya? Which reactor is the best? Anupriya I was asking which reactor is the best?

(Professor – student conversation starts)

Student: Depends on the

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Professor: X A, X A Ok, agree with you, Debian? Depends on X A she says

Student: Reactor combination, in combination with reaction...

Professor: I said which reactor is the best, first one reactor. Afterwards we will see. P F R Ok. So P F R what is the area I have to take?

Student: 0:08:16.4

Professor: Where? So if I have,

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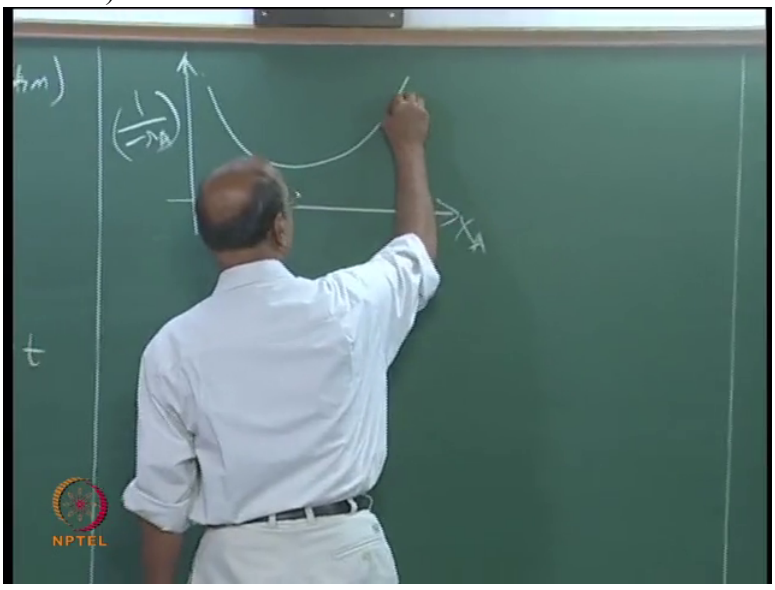

let us say this is X A f, yeah that is X A f, so total area under the curve I have to take, right? Yeah. That is not bad, Ok. That is not bad. Someone was telling that depends on conversion or something, Oh Anupriya? Yeah what do you mean by that?

Student: We need a 0:08:44.1,

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it will be minimum of that curve then if you are taking M across then that area will be lesser than the P F R.

Professor: Yes, definitely, what she said is right. It depends clearly on the, yeah conversion at which you are

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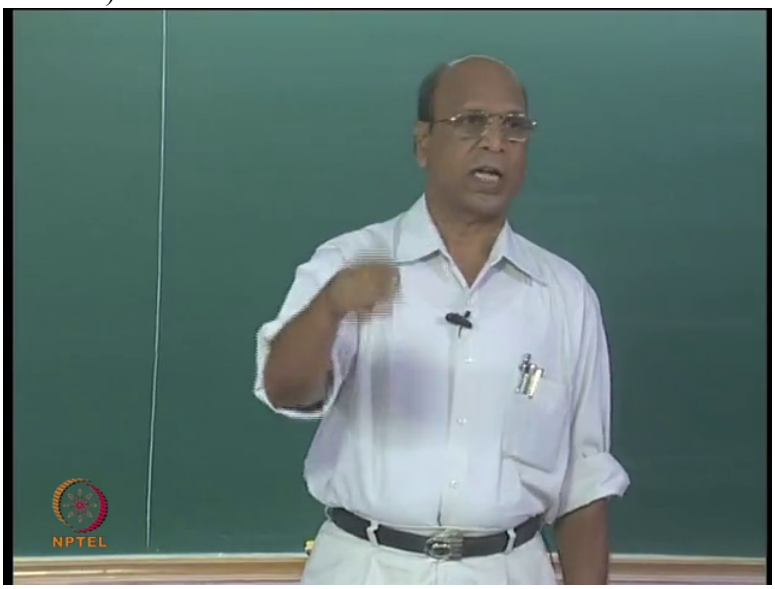

trying to do the thing, Ok.

(Professor – student conversation ends)

So if I take that the conversion is corresponding to the maximum rate, somewhere here, this is the maximum rate, so that is why 1 by r is minimum. Ok, 1 by r is minimum. So here if I have somewhere here, then C S T R is the best. So we think that always C S T R is very bad,

no? Normally it is giving large volume and all that. This is one case where C S T R is really best. Ok.

So that is why normally what we can say here is the reactor selection depends on whether you have small conversion or large conversion. So when I have small conversion, so that means I have similar versus X A, so then you have something like this, and till here if I take, anywhere between, no this point, this is the conversion which is corresponding to maximum rate, X A 1 I say,

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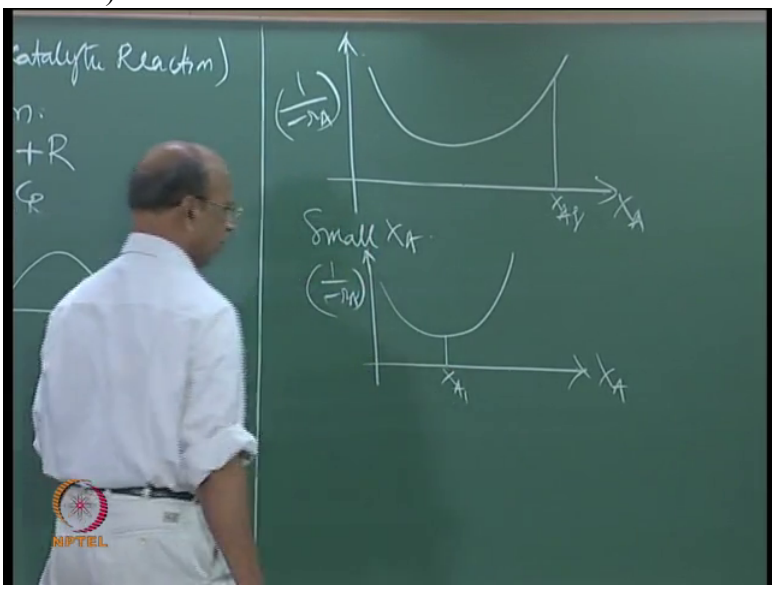

X A 1 corresponding to where? X A 1 corresponding to maximum rate,

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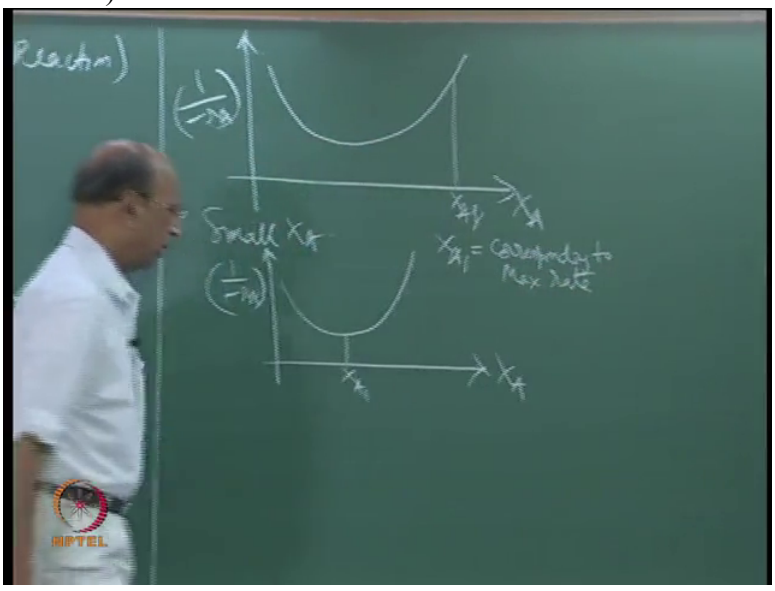

so till that point always mixed flow is the best.

This is mixed flow,

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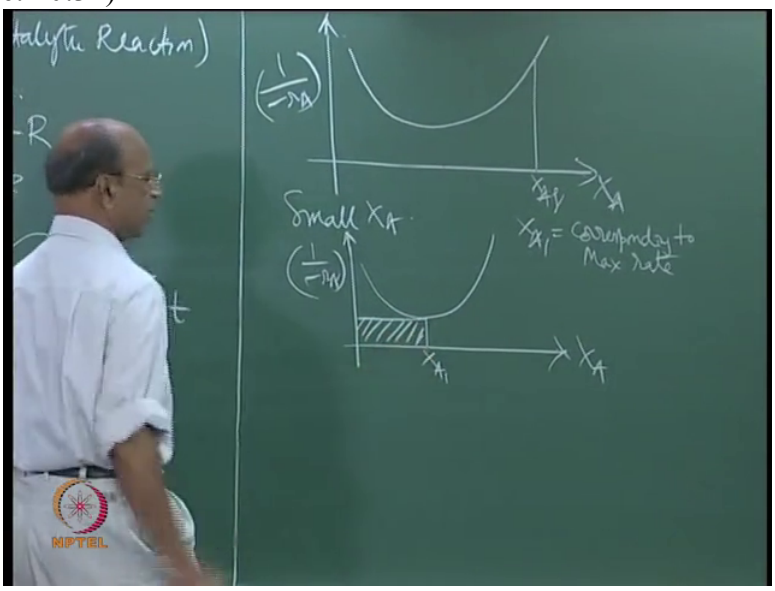

M F R and

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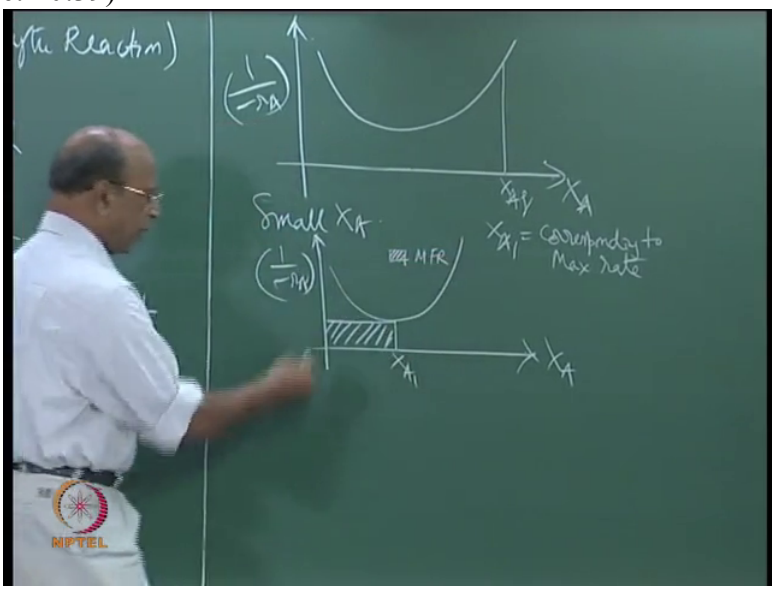

if I take P F R here, this is the total area, this entire area.

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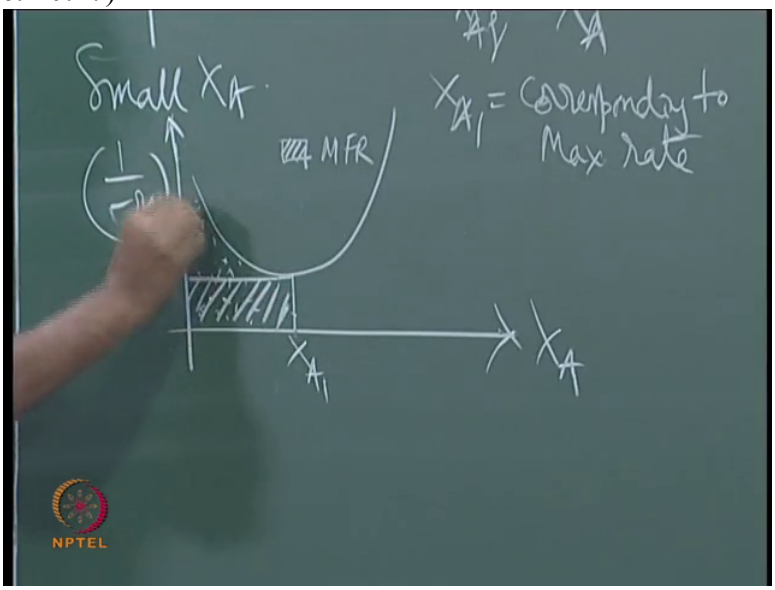

Ok, P F R,

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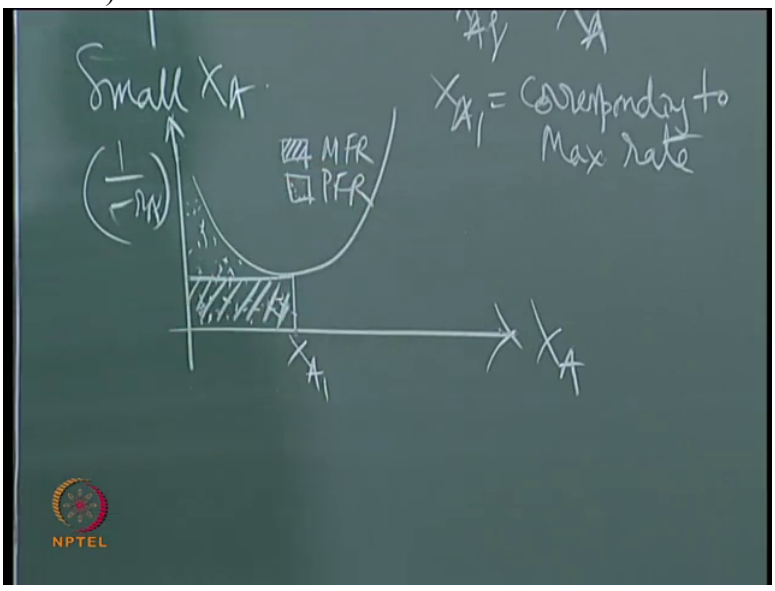

Ok good. So when I have intermediate conversions, intermediate conversions means you know somewhere here, till here. So when I plot that, so X A versus 1 by minus r A like this, so my conversion corresponding to maximum rate is somewhere here, X A 1 but I am interested somewhere here. Ok.

So that means, anyway, again for P F R I will have all this.

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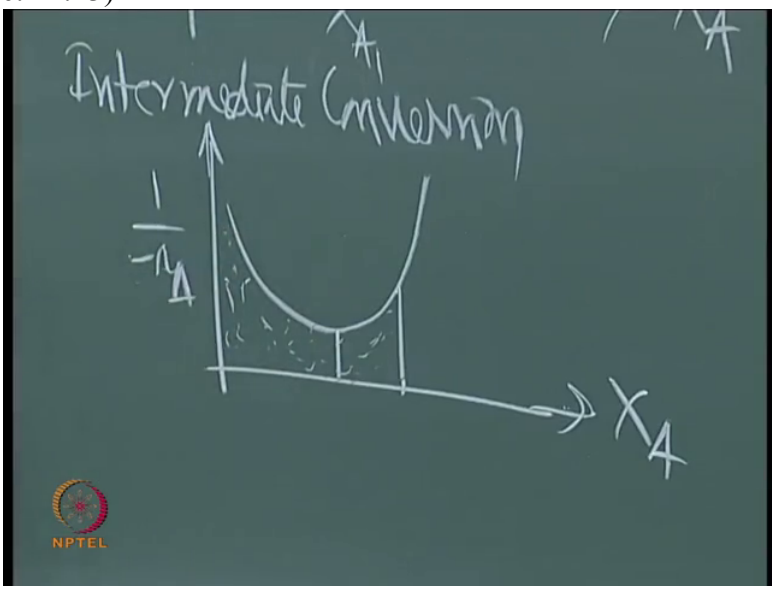

And for M F R? From here to,

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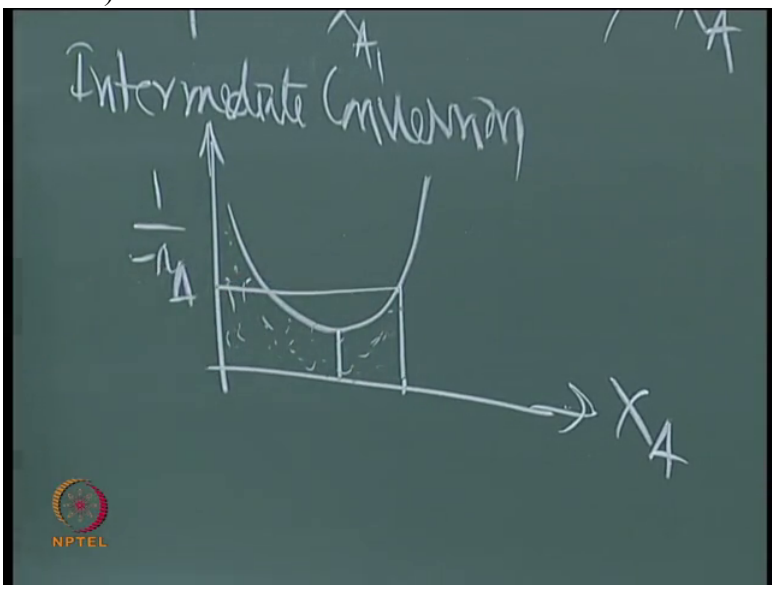

this is M F R.

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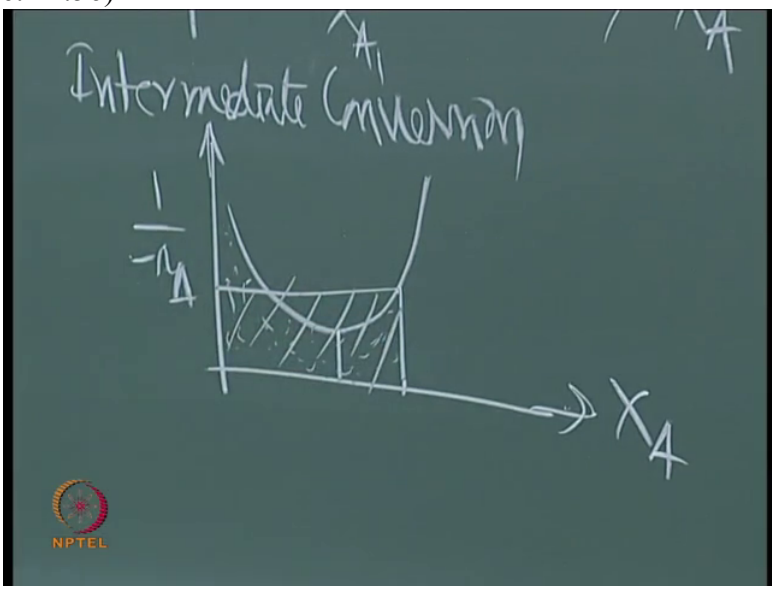

So sometimes both may be, both areas may be same. Then which reactor you choose?

(Professor – student conversation starts)

Student: 0:12:08.5

Professor: If conversion is intermediate, where this area, Ok I have here again M F R

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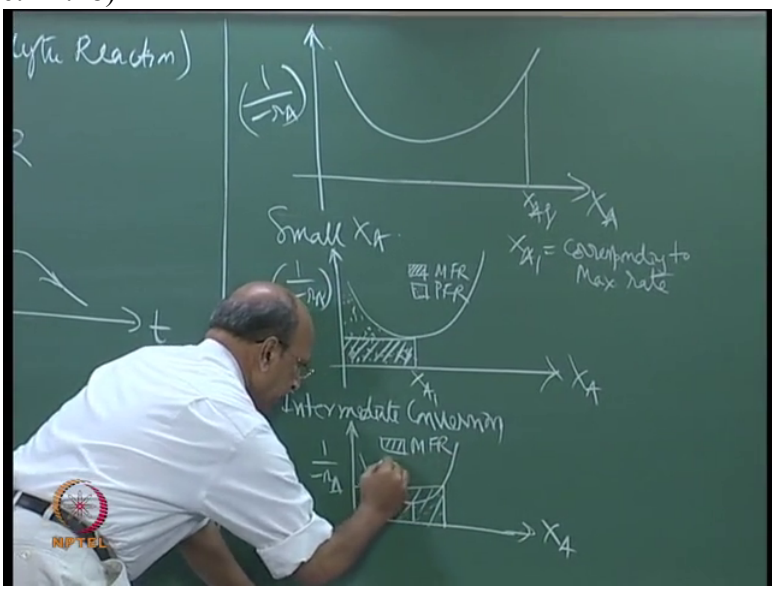

and P F R,

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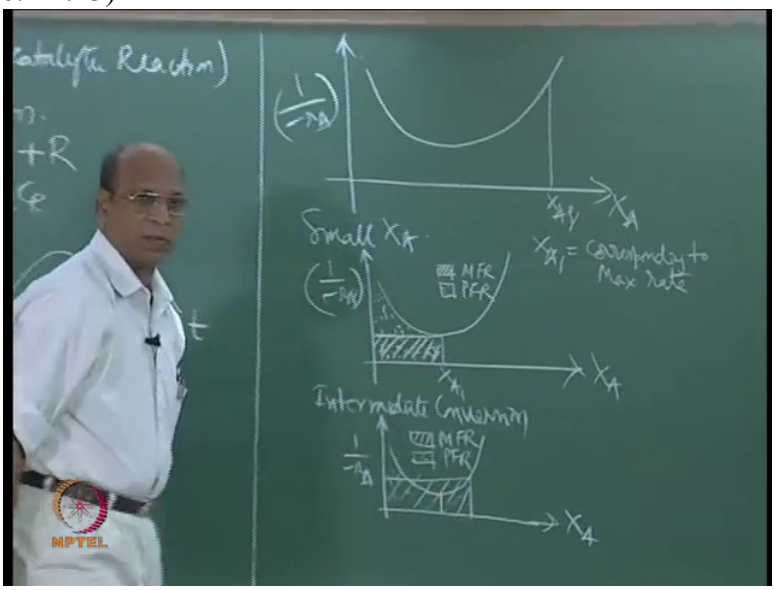

both areas are same, equal to, Ok sometimes you may get that, you know in-between,

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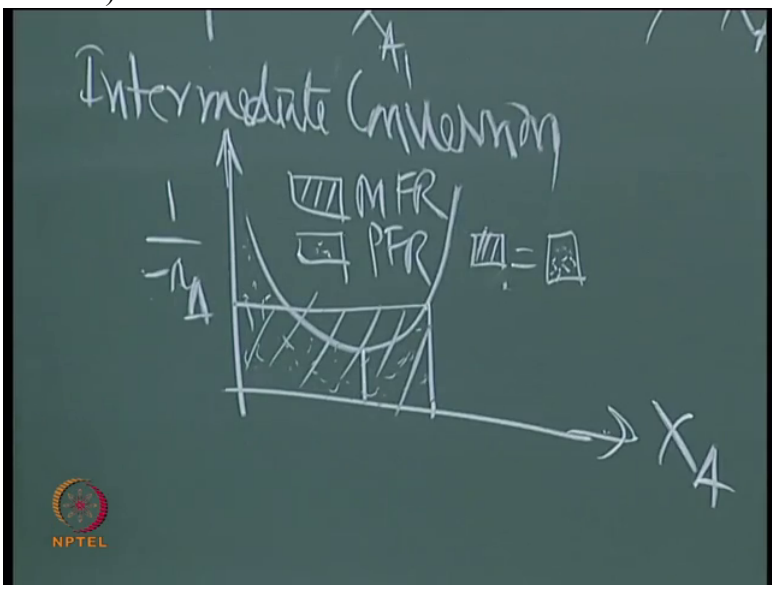

yeah which reactor you choose, Swamy?

Student: Whichever is more economical

Professor: Yeah, you tell me whichever is more economical. Which is more economical?

Student: P F R

Professor: How do you say that? It is giving same volume, M F R is

Student: Anything

Professor: Why?

Student: 0:12:51.3

Professor: Even for P F R one cylindrical portion only required.

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Student: 0:13:01.1

Professor: Even for M F R, only one cylindrical portion is required. That is what he is telling. Abhishek is telling no, go for whatever is the cheapest. Yeah, but other than cheapest,

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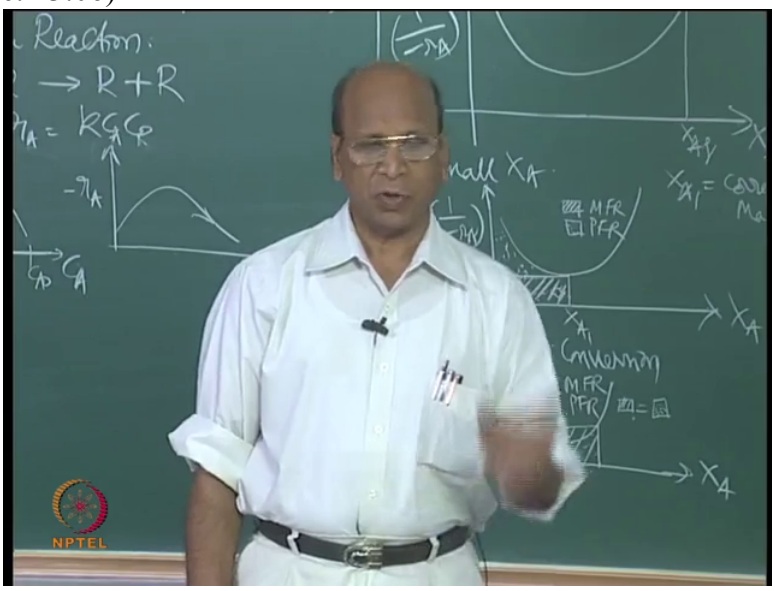

do you have any other criteria?

Student: Order of the reaction

Professor: 0:13:10.3.

Student: Temperature control.

Professor: Temperature control, Ok. Temperature does not matter. I think, you know, I can control. Then what is the thing? I am removing the restriction. It is Ok, temperature control is

not very that much crucial. For me somehow I will manage. Is there any other point? Yeah which is easy to operate?

Student: M F R

Professor: M F R. Why P F R is difficult to operate? Because I have to explain all the....

Student: Verify

Student: There is no ideal plug flow reactor.

Professor: Yeah. There is no ideal P F R anywhere. It is only in our mind. Correct no? It is only in our mind, ideal P F R. Where is ideal P F R?

(Professor – student conversation ends)

Because as long as you have walls, you have some liquid which is sticking to that. The velocity profile is different there near the wall. So that is why, theoretically there is no, particularly for you know, liquid and gas flowing through pipes, right as long as, but whereas if you have coal and then you are burning on a, what is that conveyor belt and all that, so then you will have, definitely no problem. I think excellent plug flow you can have.

That is why whenever you have this kind of pipe flow for homogenous reactions, theoretically there is no, I mean, plug flow. The reason is that the velo/velocity, flat velocity profile you get only when you have velocity equal to infinity, theoretically infinity. Ok, that is reason why whenever we have a choice between P F R and M F R, people jump to M F R, Ok, so that is why.

So the next one is, next alternative is high conversions, so that one we have 1 by minus r A versus X A, similarly I have again, somewhere here we have X A f. Now which reactor is best?

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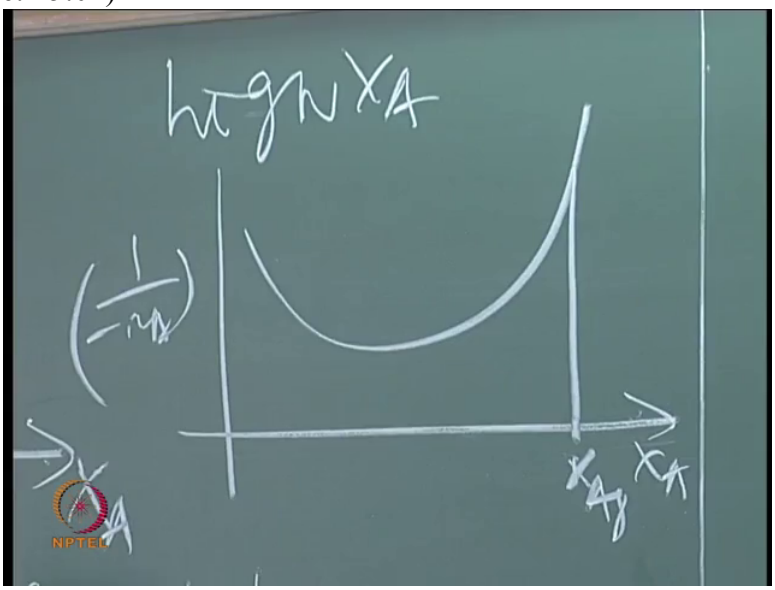

P F R, because only this area, that is next. That is next. Yeah, so this is P F R,

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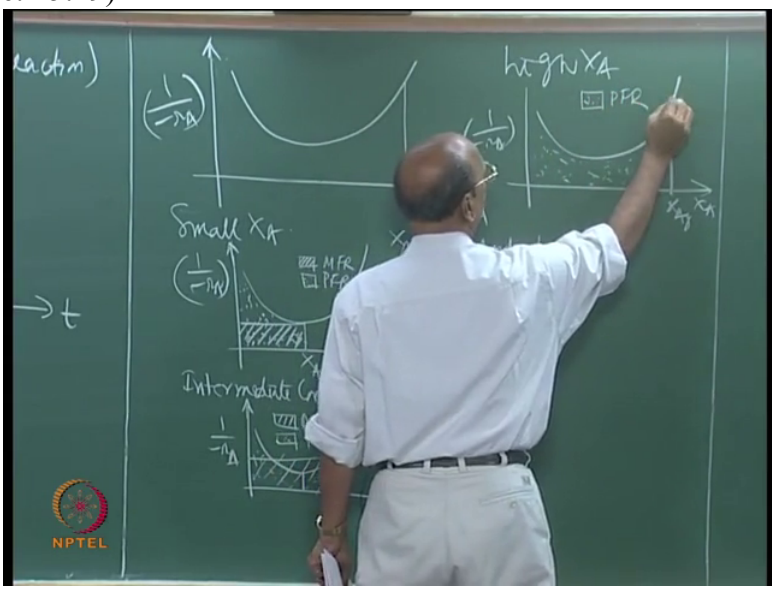

M F R will be this one.

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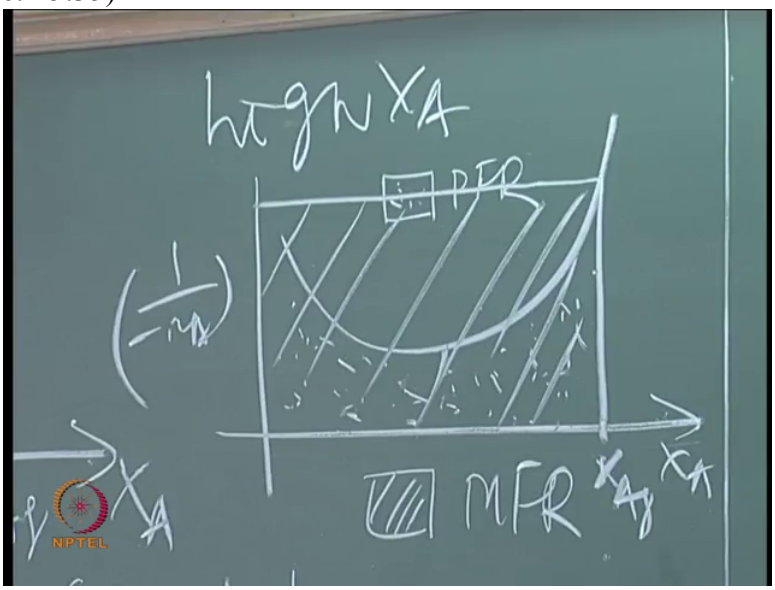

Very good. Ok

Now we will go to combination of reactors. These are individual reactors what we have, either P F R and M F R, now individual, now I think you have become masters. So I think I do not have to take much time to explain. Yeah this is 1 by minus r A versus X A. So the best thing is till maximum rate, yeah, maximum rate M F R and then till this X A f, P F R, yeah first C S T R

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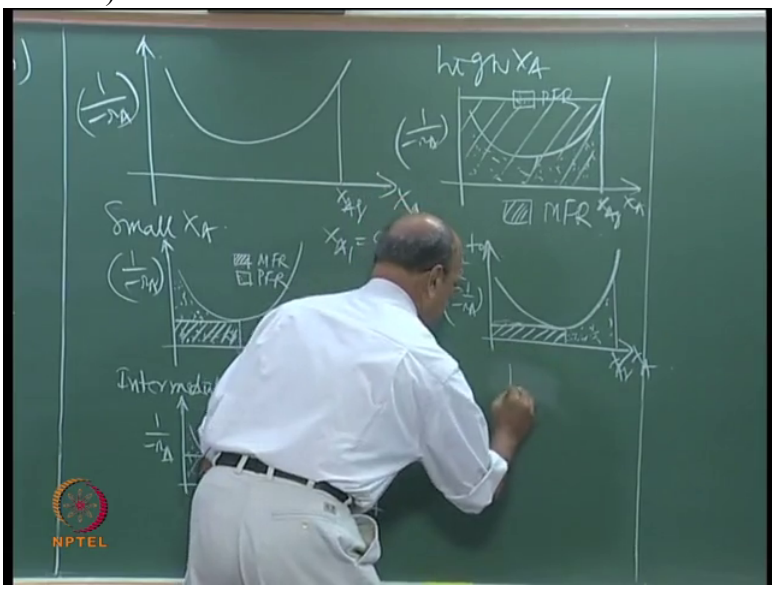

then we have M F R. Here I have X A 1, X A 1. That is the best

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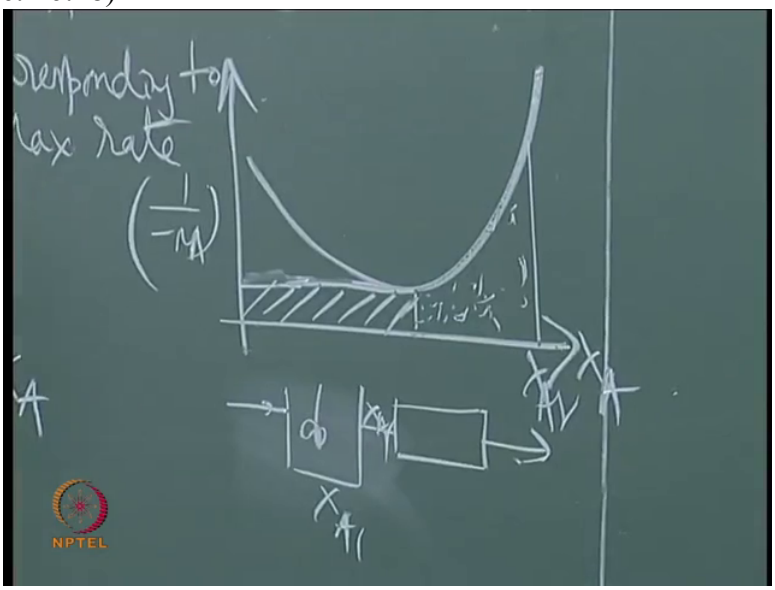

setup. Two.

There is another best setup also. You bring mass transfer and reaction together. What is that best setup? Yeah, up to maximum rate, we put 1 by minus r A versus X A, this is the one.

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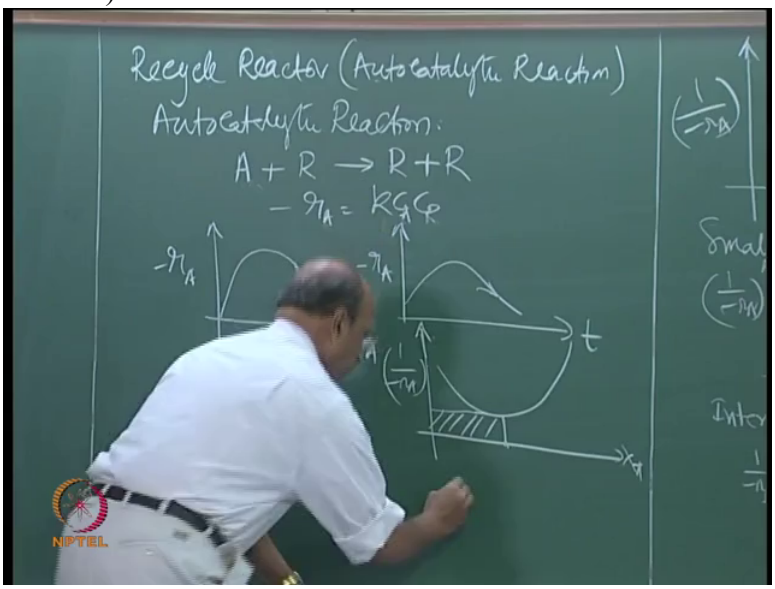

So I will put a C S T R, Ok, so then I have here. It is X A f, right. This can go back again,

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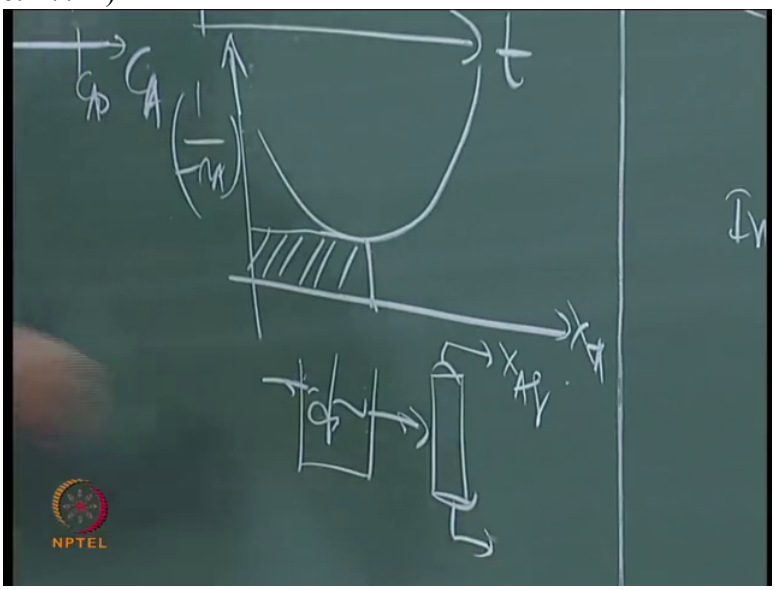

that is Ok, right? So yeah, able to follow, Swamy? Yeah, what is happening here?

I want my 90 percent conversion, that is true. My conversion may be 90 percent. But what I do is I conduct the reaction only till X A 1.

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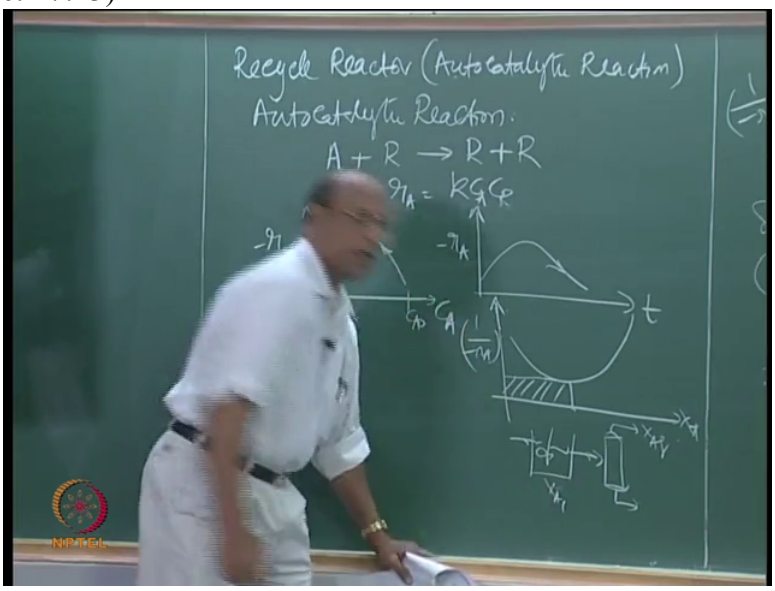

And use either absorption or distillation procedure to, that is what you are doing in distillation, no? You are only just increasing the product, one of the component's purity, right?

So that way, you can now go to X A f and this is X A 1. So if you are able to combine these two, then we have the best thing because reactor volume is decreasing. It does not mean that this is economical. As he said finally, finally economics only, either this

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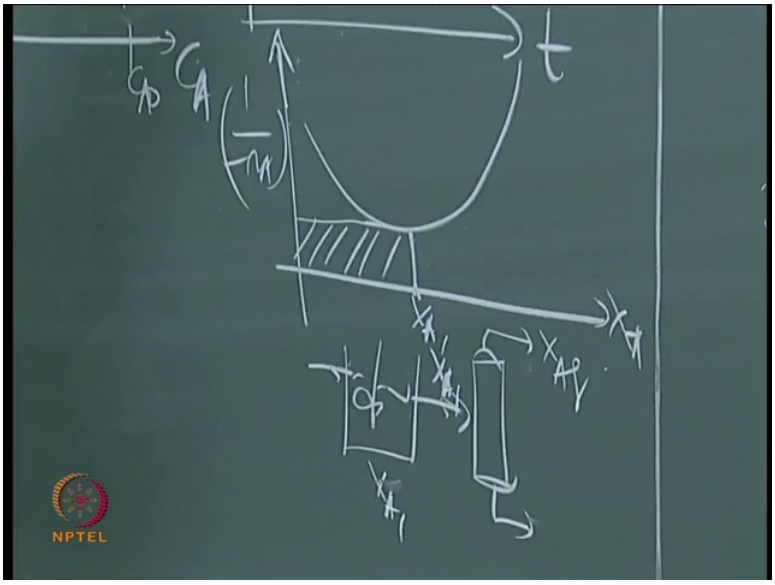

or this or individual reactors.

Or the next one recycled reactor, Ok, good. So physically discussing why at this point for example, Ok this one, why it is giving that is the best reactor what you have if I operate this one at X A 1? Ok, X A 1, why?

What is

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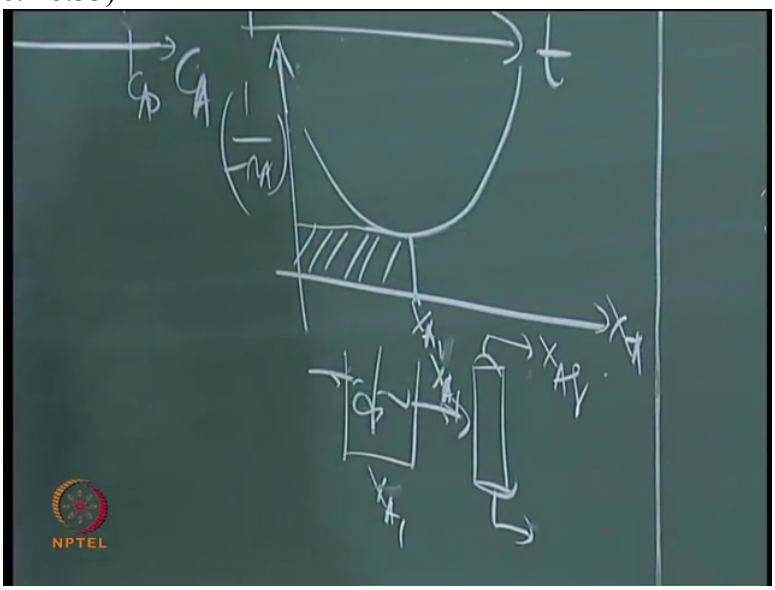

really happening there? Why now suddenly this inefficient fellow has become very efficient. Or in this insert, now we are saying mixing is better for this reaction. Correct no? Earlier we said mixing is not good at all. Now we say mixing is good.

You know

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that much physics we should be able to imagine a little bit.

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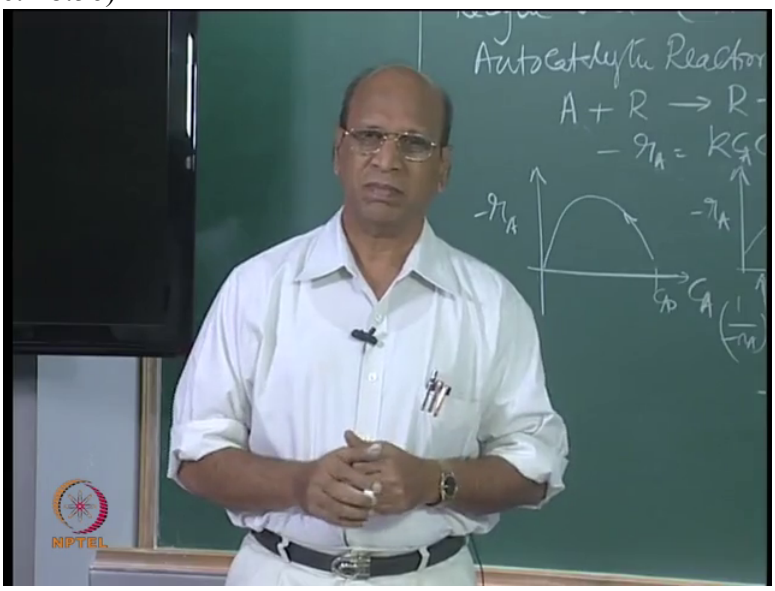

Why earlier we were telling that, you know mixing is very bad for reaction and all that. But now we suddenly say that mixing is very good. You go for only mixed flow.

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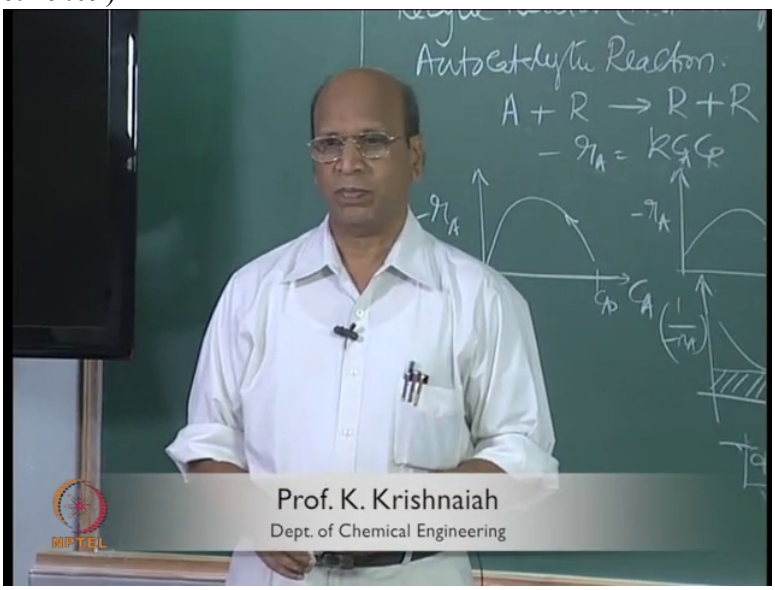

0:19:13.0 any idea? Not able to imagine? Can you tell what is the reason? What is the reason why mixed flow is very good now for autocatalytic reaction?

(Professor – student conversation starts)

Student: Even if it is partly converted the probability of unconverted reactant mixing there in the C S T R will be less when we have no converted mixing

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Professor: What do you mean by probability? And we are deliberately mixing both?

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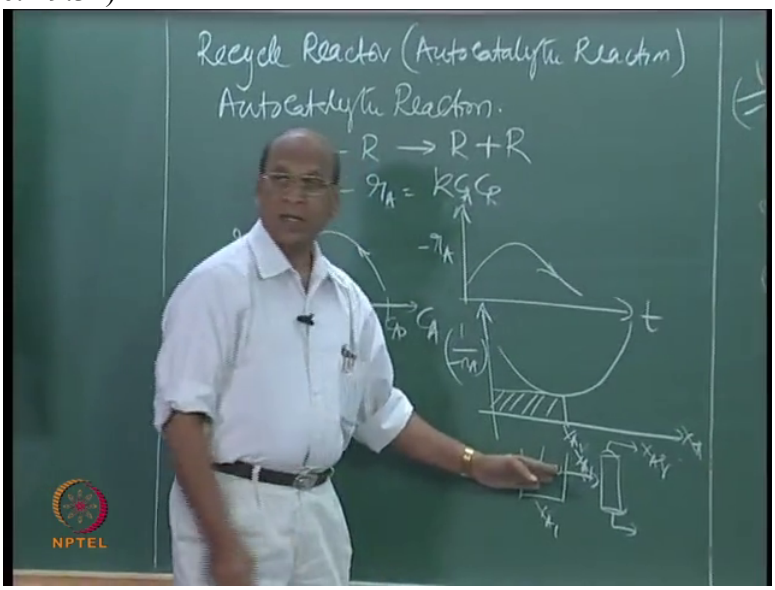

Because there you know where you are continuously feeding what is happening? The fresh reactant is mixing with the product where we have the product conversion is

Student: Very high

Professor: yeah X A, not very high, X A 1, very high means it is becoming again very inefficient. Ok, at only one point it is excellent. Yeah, Savita?

Student: Wait for the reaction to proceed and we are mixing the initial with the products. So the rate will be high

(Refer Slide Time: 20:00)

and we will get the required conversion...

Professor: Yeah because you are mixing product with

Student: The rate will be high and the required conversion...

Professor: Very simple thing is this equation.

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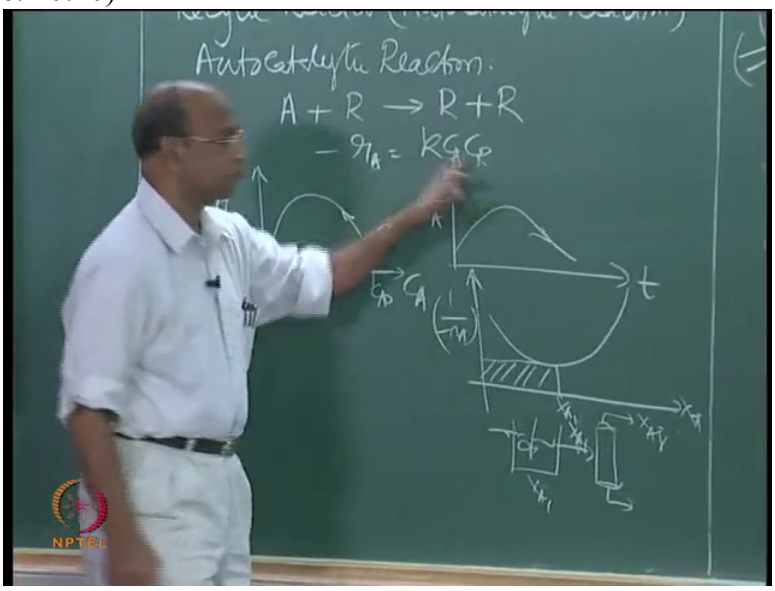

Combination of this C A C R is the best in,

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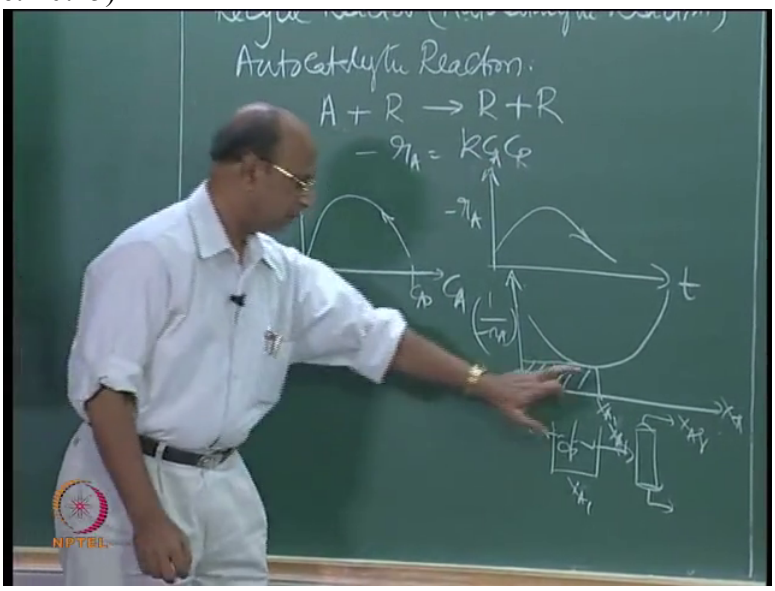

in mixed flow reactors and how many, how many rates you have in that? How many rates are there in this system?

Student: One rate

Professor: Only one rate which is equal to the maximum rate, right? So if you take any other rate, it will dilute, correct no? You will have different conversions. So that is also the reason why plug flow is bad here. You know all

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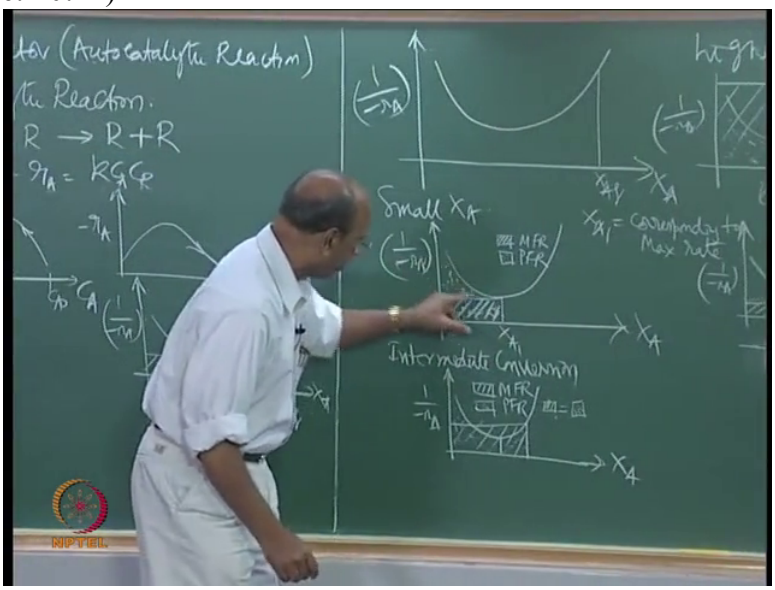

this area plug flow is bad because there are so many rates. Those rates are not good here, right.

(Professor – student conversation ends)

So that is why this extra area will come because along the length of the P F R you have so many rates. Whereas here,

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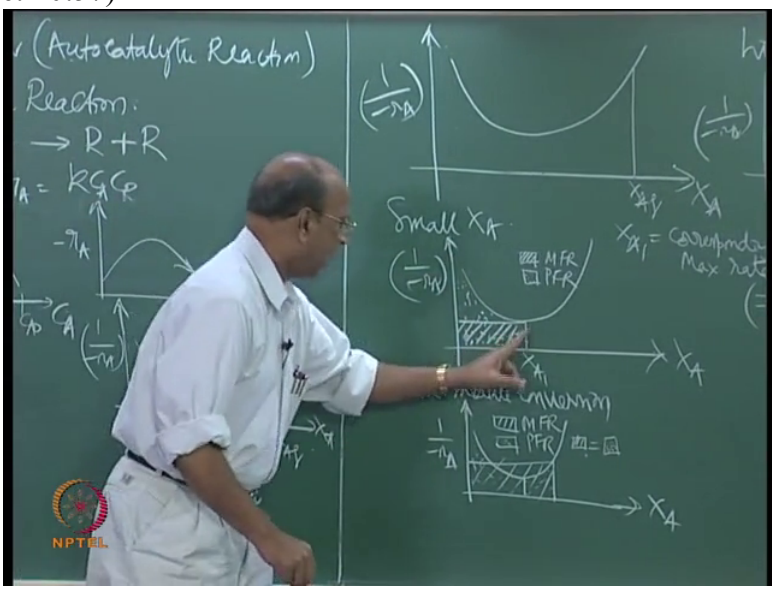

I have only one rate which is the maximum rate and I am able to operate the system only at that maximum rate. So it is not, you know, no contamination, no dilution anything, nothing.

So that is the reason why, this you know, every dog will have its own days people say no? So this dog has its own day,

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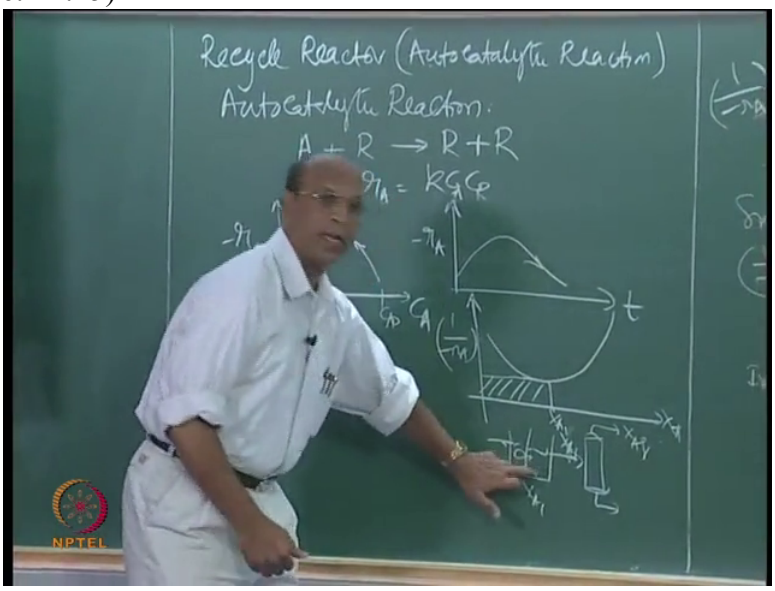

mixed flow reactor. Best. So at least it will be proud. I mean every one of us in the nature, you know should be proud.

So that is why you know this is one of the best reactors, Ok. If you understand this, then going to recycle reactor is easy. Another possibility for autocatalytic reaction is one reactor, Ok but you see here, here I have two.

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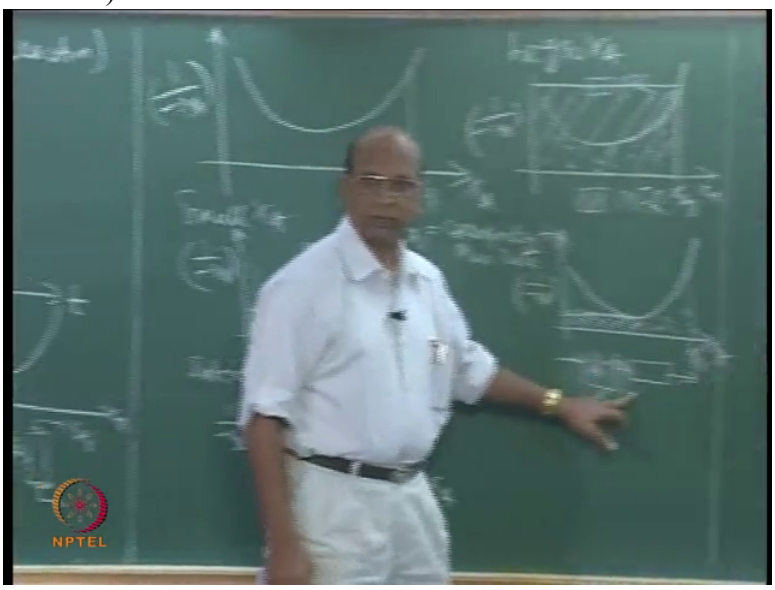

If I want to go for slightly higher conversions, right? And here also I have 2. May be

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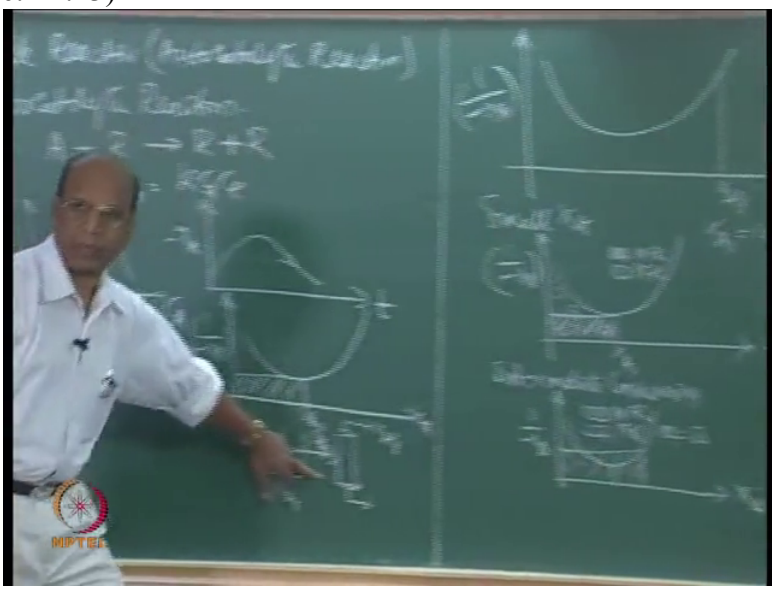

mass transfer and reactor both. This is mass transfer equipment, may be distillation column and this is the one.

But if I go to actual

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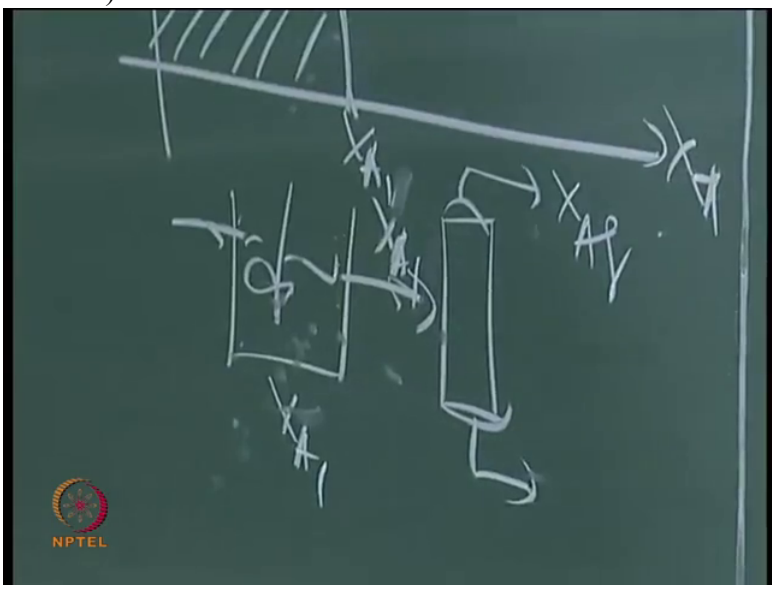

recycle reactor then we have only one reactor but only thing is recycle you have to, you have to put a pump and then recycle it through the inlet. That is all what we have there. So why it is better than, as one reactor sometimes it is better, sometimes only it is better. You have to again calculate the overall economics.

Why it is better is that for autocatalytic reaction you need some product for reaction. Now if you are able to choose that recycle ratio where you will get the optimum recycle ratio so that inside the reactor you are going to have, it is a plug flow reactor, the average of all those reactor, all those rates are very high. The average rate.

You know, I do not know still you are able to get me or not. When you are doing integral d X A by minus r A, that means nothing but you are averaging that. All the rates you are trying to average and then you will get that. So in normally N greater than zero, that average is more for plug flow reactor. That is why you get more conversion for a given volume or vice versa.

And in mixed flow because you have only one rate, and that rate corresponds to your outlet rate which is X A f, that means rate is smaller no? X A f is 90 percent. Rate is small. So you are able to operate the mixed flow at only one rate which is the lowest rate possible for that reactor because you have fixed X A f equal to 90 percent.

So now what is the volume? 1 by r A, correct no? X A by minus r A equal to V by F A naught. So that is the reason why you should have automatically very large volume for the reactor. Ok again I am repeating the same concepts only, Ok. That is the reason why. Because you should not forget you know, these concepts. Very simply, beautifully can be explained all these, right.

So that is the reason why we are not able to get very high conversion for a given volume or for a given conversion you will get more volume. This is for N greater than zero. N equal to zero? Which reactor is the best?

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(Professor – student conversation starts)

Student: Both are

Professor: Both are best. Now you have to give physical reasoning why both are best. See that is

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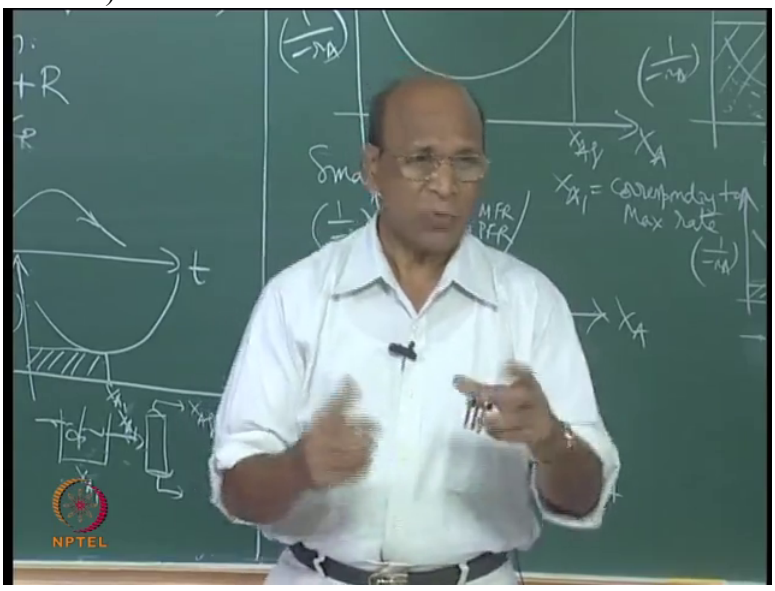

what is always required I say, that physics, that physical reasoning.

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Student: Concentration

Student: V by

Professor: I have been telling, you know very typical. I ask her, everyone answers

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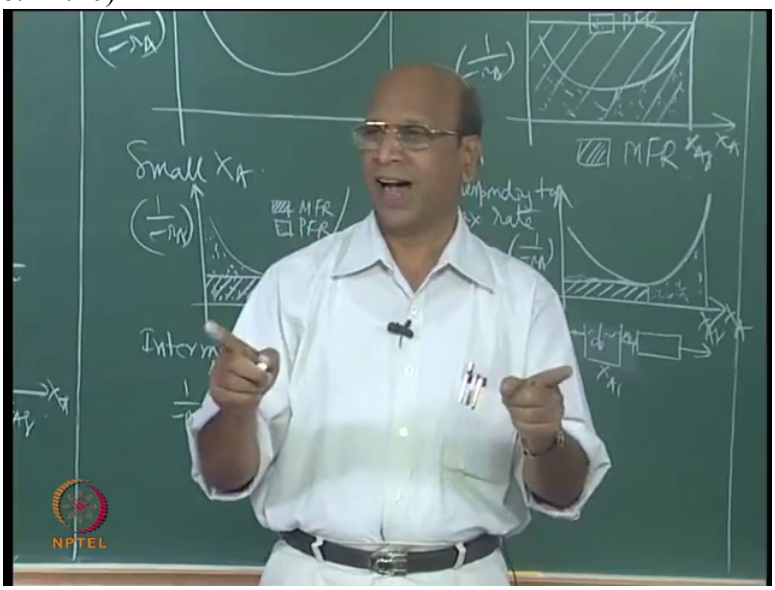

right or wrong except her. (laugh)

Student: V by F A zero will be the same.

Professor: V by F A naught?

Student: Will be the same

Professor: Will be same. Why I am asking? You are talking mathematics, I am talking about physics. We should have chemistry together, (laugh). No, better chemistry they say no?

Student: (laugh)

Professor: If 2 people work in team means you should have better chemistry. That is what everyone uses. I do not know whether they understand or not. But anyway.

Student: (laugh)

Professor: So everyone says that yeah, that team has excellent chemistry that is why it won. What about physics we do not know. What about mathematics we do not know (laugh). So I think Simi you were telling about V by F A naught equal to something mathematics, I am asking physics. Unless our chemistry is good you cannot answer, that is also there. (laugh). Ok, Pooja, are you trying to tell something?

Student: Concentration change

Professor: That is very simple I say. See why, what is happening is you know. You would have got that point. Because at this point of time you should have not got that to your mind. But we know that, we feel that. Why? Because for zero order reaction, the reaction is independent of

Student: Concentration

Professor: Concentration and how P F R affecting concentration, how M F R affecting concentration.

(Professor – student conversation ends)

M F R affecting concentration because it gives the lowest concentration, Ok corresponding to that outlet concentration. Whereas in plug flow you have a concentration history from starting to C A naught to C A f. Ok. There is again concentration history. The overall rate is again definitely better than this M F R that is why we are getting better.

For zero order it does not matter. Concentration is not coming into picture. So whether you mix or do not mix, it is same. That is why you have zero order for both same. Because these things physically you have to explain, not mathematically, mathematics also required. But I think, first physics then mathematics, right. So that is the reason.

So that is why if you take the recycle reactor now, Ok, recycle reactor, what is the objective now? See we have 2 things now. We understood what is recycle reactor. We have an equation V by F A naught equal to that entire thing, right? And now have also understood what is autocatalytic reaction, and we now say that autocatalytic reaction definitely needs some product to be formed.

Now the question we have to ask is the conditions that are going on inside plug flow element of a recycle reactor depends on how much you are recycling. Yeah, how much you are recycling, that R. Now you have to choose that R such that your volume is minimum for a given conversion. What is that R, what is that R which gives me minimum volume for a given conversion?

You can do the other way also. For a given volume, what will be the maximum conversion, Ok? I think either this problem, but I think let us see only the volume thing. Pooja, able to define the mathematics, now I am talking about mathematics, Ok, yeah. So now what is the mathematical condition for this?

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First of all you understood the condition?

(Professor – student conversation starts)

Student: What is the recycle ratio such that the conversion, the volume should be minimum?

Professor: Why? Why recycle ratio I have to choose? I am asking sometimes stupid questions

Student: Small product we have to form, for that

Professor: Yeah. Autocatalytic

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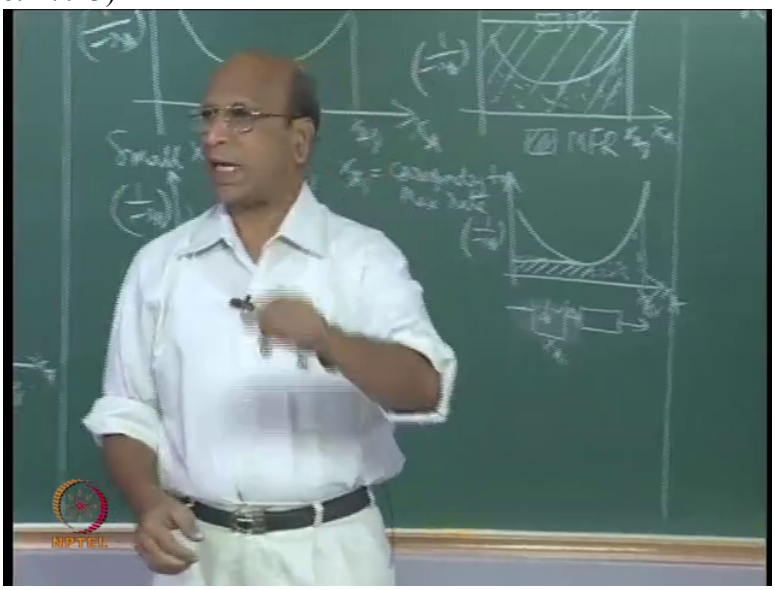

reaction needs some amount of product. Now this product is coming through

Student: Recycle

Professor: Recycle. What is that recycle ratio which will minimize my

Student: Volume

Professor: Total volume, that, you know means maximizes the R throughout the reactor, because it is average, Ok, throughout the reactor, that is the mathematical problem now. So what is the mathematical condition? double derivative? Ok, double derivative will come first. What is the first derivative?

Student: That d V 0:28:15.0

Professor: Yes, that means the condition here is, I have d V by F A naught by d r equal to, with respect to what I have to differentiate?

Student: With respect to r, rate of the reaction

Professor: With respect to r, because that is what. What is the optimal recycle ratio? Optimal recycle ratio which will reduce my volume to, I mean lowest, minimum volume. So this is equal to zero. Ok and one can write this also as tau by C A naught, that is Ok. Right.

(Professor – student conversation ends)

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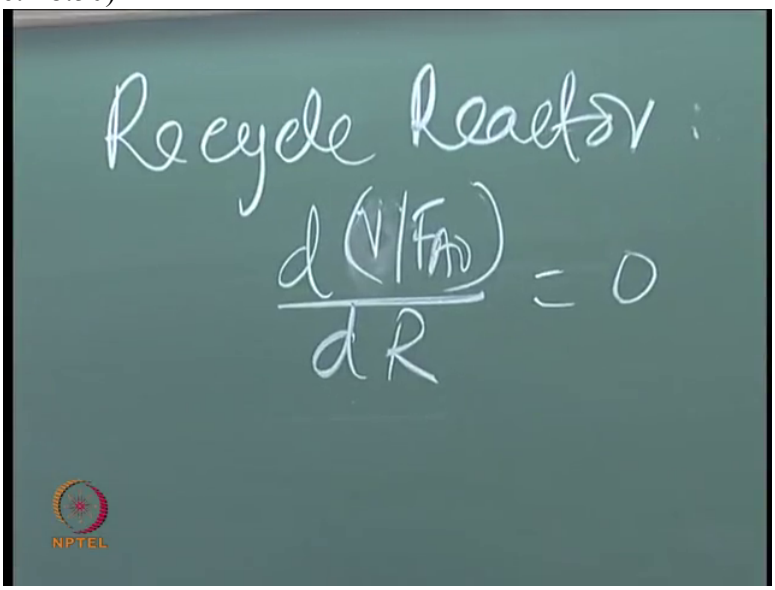

So that is the mathematical problem now. So how do you solve this problem? So whenever you have, of course I have, where V by F A naught equal to, anyone remembers? Sushmita?

(Professor – student conversation starts)

Student: R plus 1 into

Student: R plus 1 into

Professor: Excellent, R plus 1 into

Student: R by R plus 1 X A f

Student: To X A f d X A by minus r

Professor: Yeah, so now you have to differentiate

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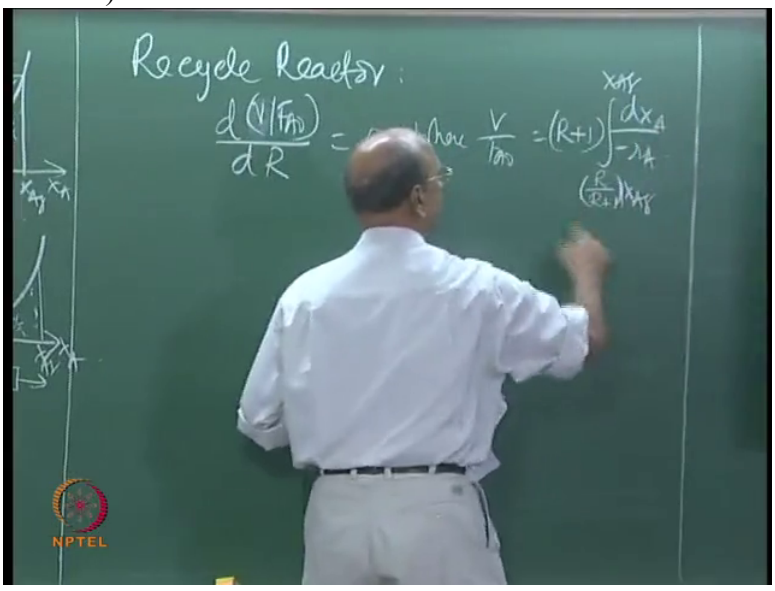

this. Ok,

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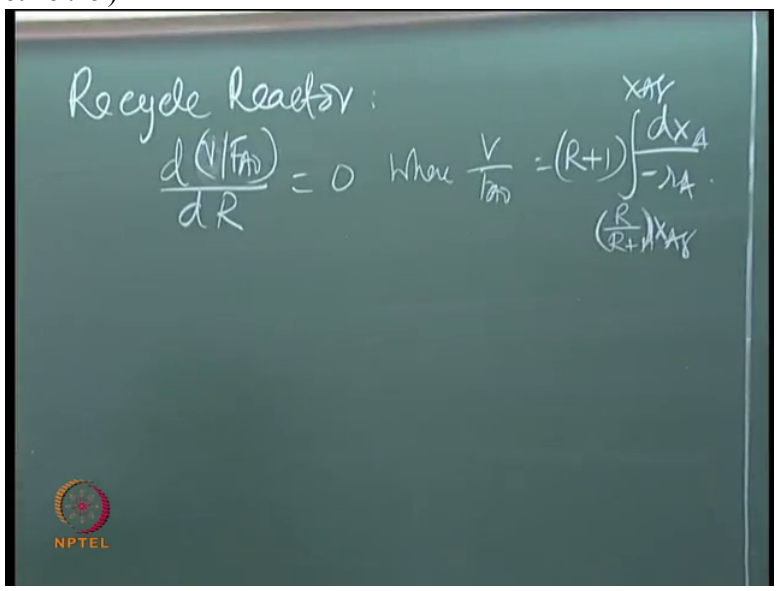

which is not a simple task.

(Professor – student conversation ends)

That is why I think I really like Levenspiel. He gives again some mathematical clue for us. There is a formula called Leibniz formula for this kind of integration. So the reason is here, this d R also present in the

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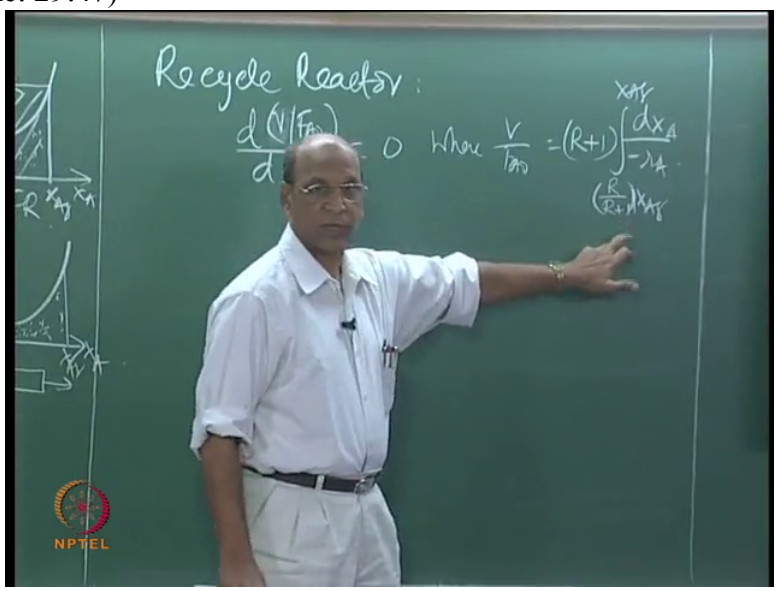

limit, in the limit, Ok.

So the condition Levenspiel gives for this kind of, you know if I have a function f R, this is function f r right, yeah so then with limits where, the variables with which we are differentiating, Ok

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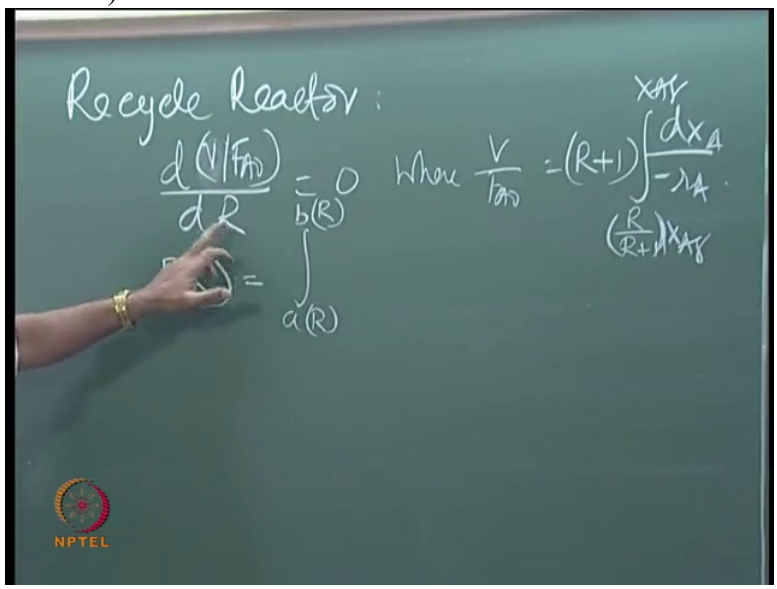

is present here, right? Because the boundaries also I changing. This is boundary, this is boundary no? Limits, when you have that kind of thing.

So yeah, this one will be X R d x

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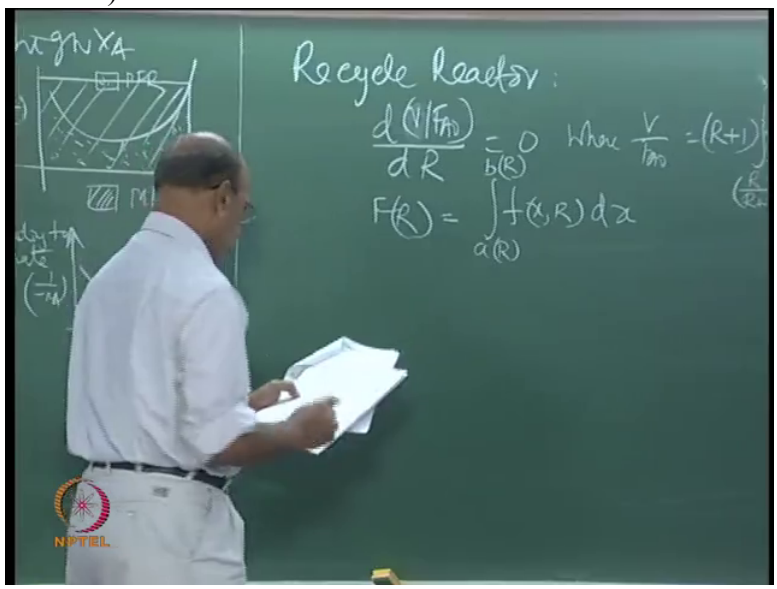

so now, the differentiation of this function is d F R by d R is equal to integral, you have to sincerely follow this and then substitute and tell me the answer. a r b r dau of, I mean

differentiation, partial differentiation of X r by dau r into d x, that is one term plus this function, this function, this function yeah b r that is upper limit into d b by d r, b is the upper limit, d b by d r minus, I also have a r into d a by d r.

So what you have to do is you have to get this term for this function, Ok and I have the lower limit, lower limit, upper limit, even lower limit is very, upper limit is very happy because it is not a function of

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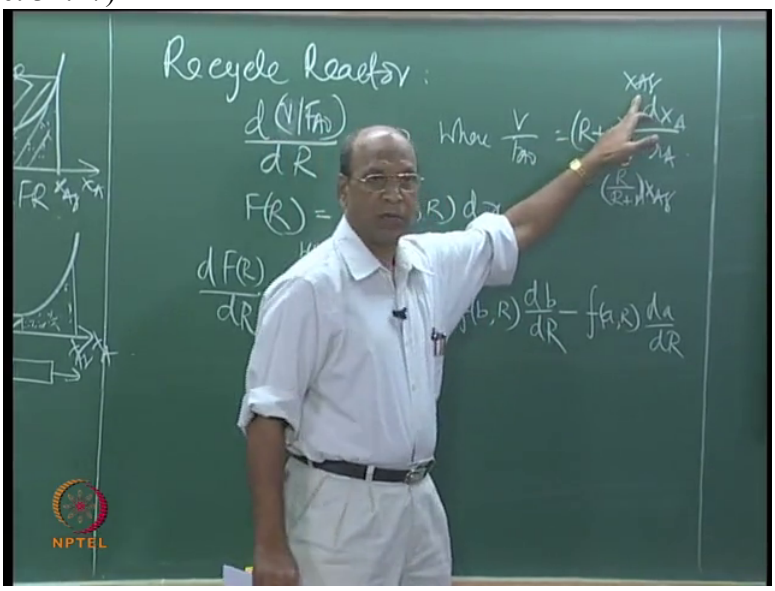

R. So that will become zero.

We like zeroes, except in the question pap/paper, answer paper. Ok, answer papers we want

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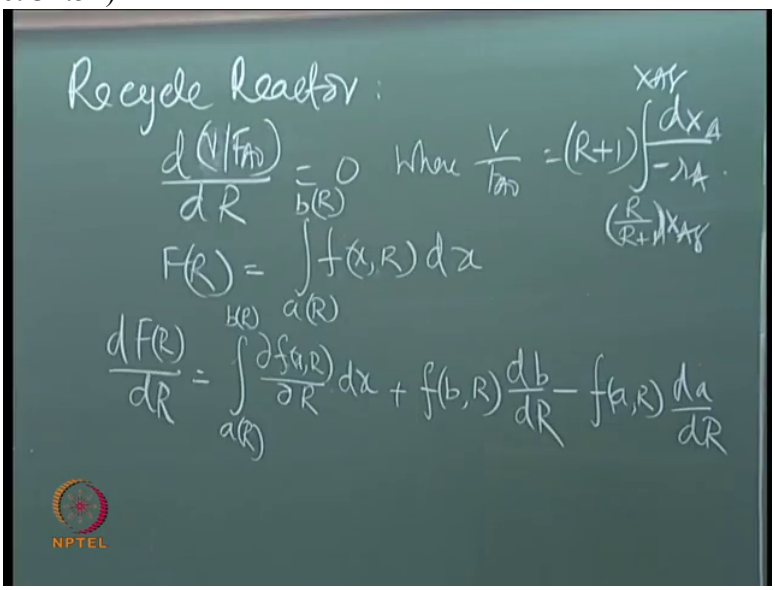

zeroes but you know 1 zero zero.

Ok, so now you want to have, this term is not present for us. Now you differentiate, have this term and then this term.

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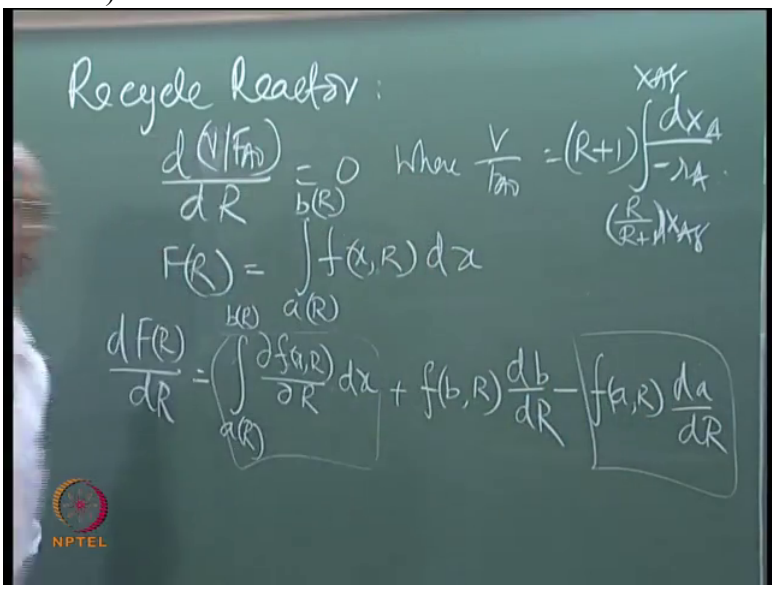

Tell me quickly. Because I am asking you to do because you have to participate in the class. You take this function as it is; you know this function is now 1 by minus r A. That is what is function now. That function is 1 by minus r A. You do not have to substitute r A as first order, second order, third order. That I will give you in the examination. But this is different. This is only; this is only straight forward now. You identify that function first. What is that function? 1 by minus r A. Ok,

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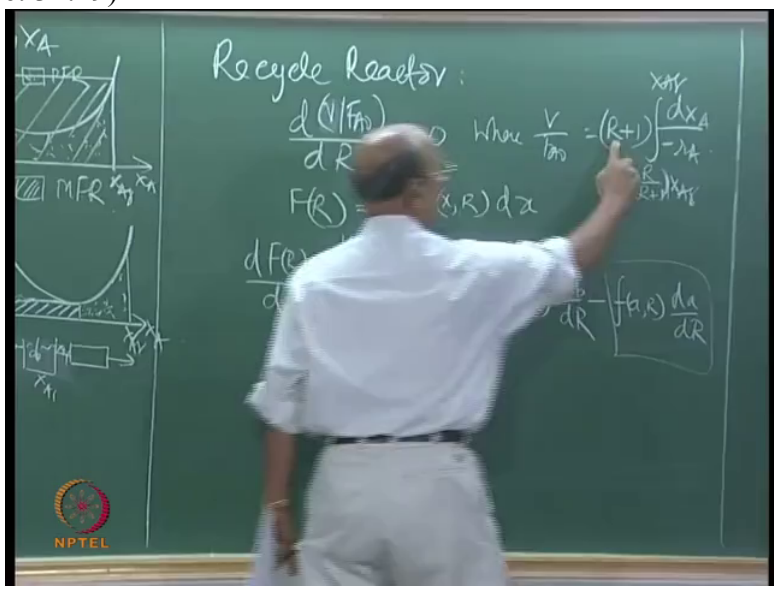

this you have to take inside. r plus 1 by

(Professor – student conversation starts)

Student: minus r A

Professor: 1 by minus r A. I mean that r plus 1 outside so I forgot, sorry that has to go inside. That is the function. Ok, so now this f of R, f of R is now R plus 1 by minus r A, right that is the one. Now it is, must be easy.

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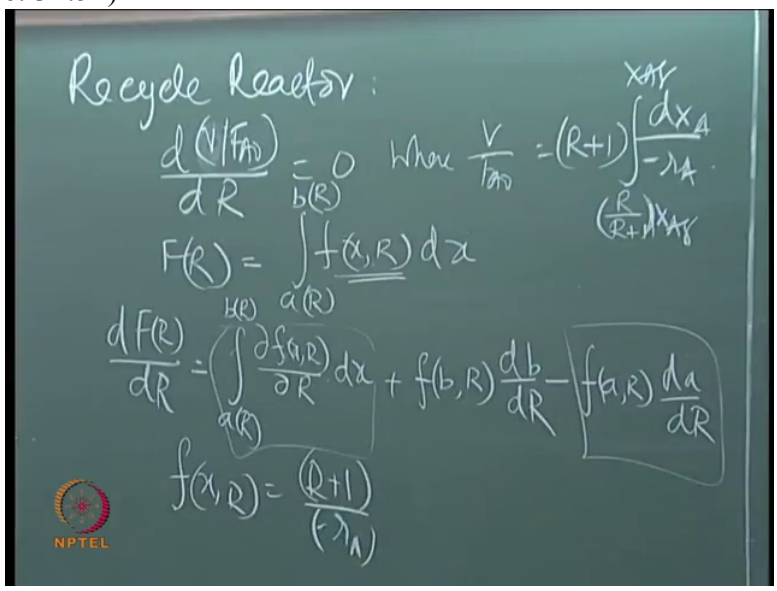

Ok tell me what is the first term?

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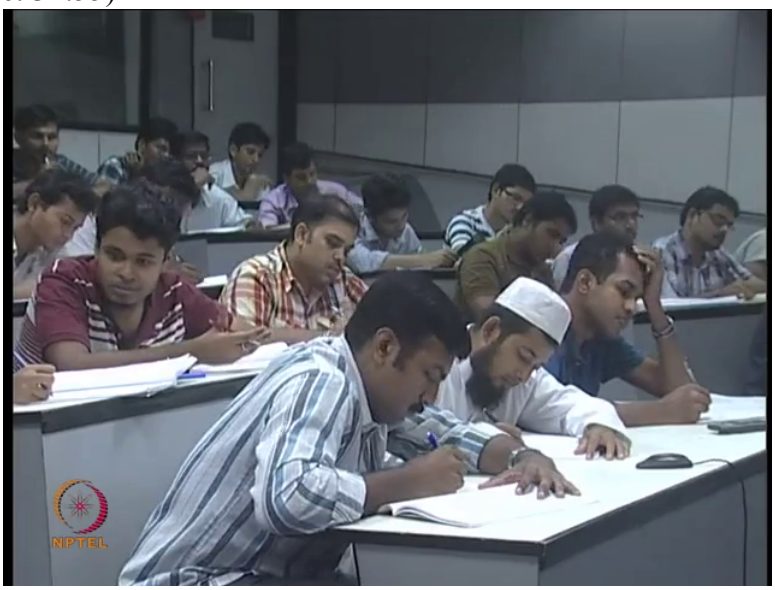

Student: 0:32:59.5

Professor: That is the first term right? Because I think only R plus 1 you have to, because partial differentiation with respect to, yeah with respect to R so that means dau, actually you want to only R plus 1 dau R. d of R plus 1 dau R, dau of R plus 1 by dau R, that is 1. So then the remaining function is only

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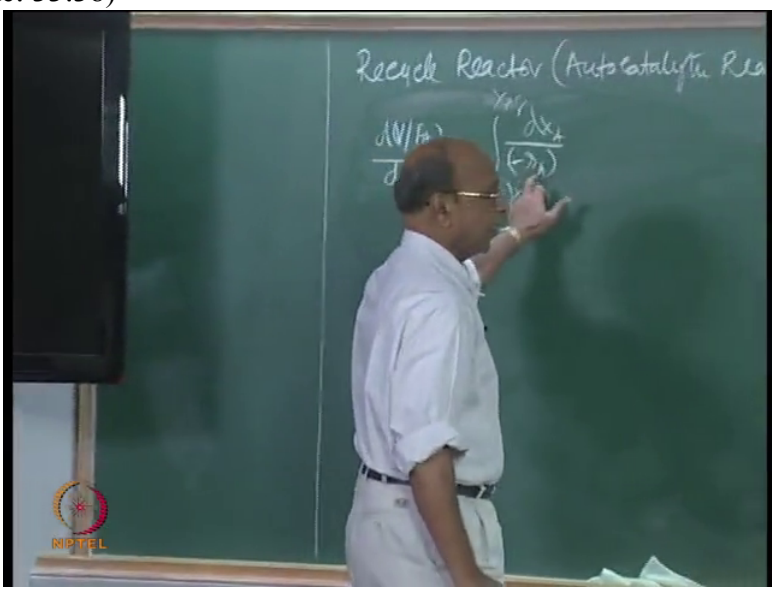

minus r A, Ok, yeah this one.

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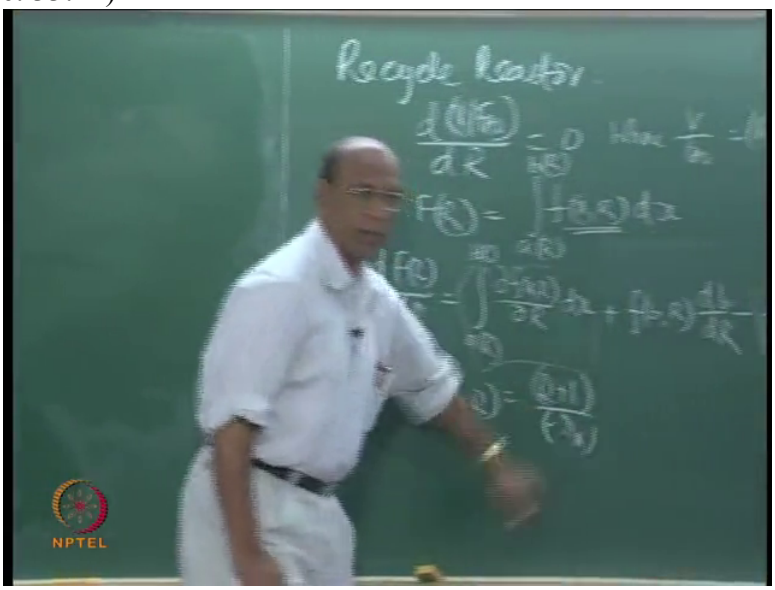

1 by minus r A, that is 1, yeah next one, zero that is very happy, next one, R plus 1.

Student: By minus r A

Professor: R plus 1

Student: By minus r A.

Professor: Yeah by minus r A, this is at X A 1, that is at the entry which is of course equal to R plus 1 and all that. Also let me write this one is X A 1,

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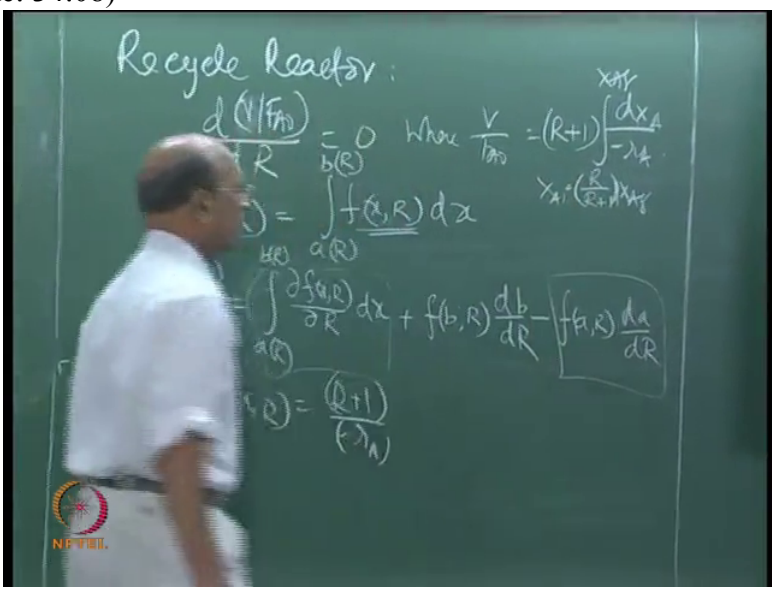

lower limit. Because I am leaving sometimes with lower limit, yeah, this multiplied by

Student: That should be R

Professor: Where is R by R plus 1?

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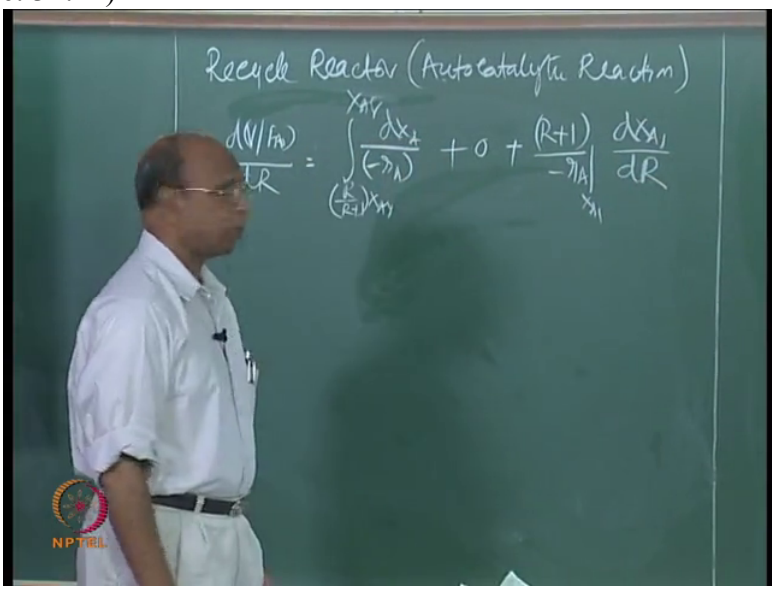

This term, this term is only R plus 1. R plus 1 divided by minus r A. Because your function you know, what is this function?

Student: Right, right, Sir, right.

Professor: This function is this.

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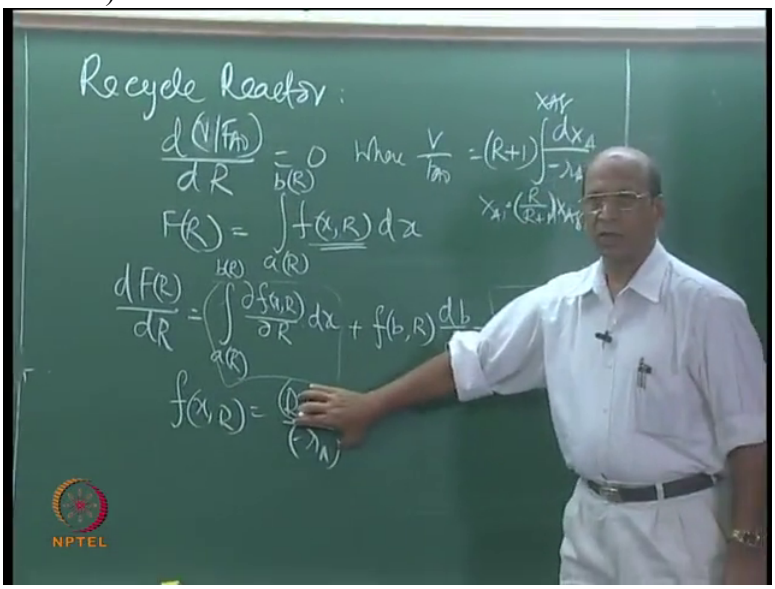

As it is, yeah copy. You are experts in copying

Student: (laugh)

Professor: Right, I think may be not from the board, from other's answer paper may be. Ok, so this comes as it is, no. I mean there is nothing wrong, nothing great thing that is involved but only thing is at X A equal to X 1, that is all. Yeah. So that is the one. This is the equation

what we have but now you have to differentiate this fellow. What is this; d X A 1 by d R equal to, this is d by, what is the equation for this, R by

Student: R by 0:35:18.7

Professor: You differentiate this,

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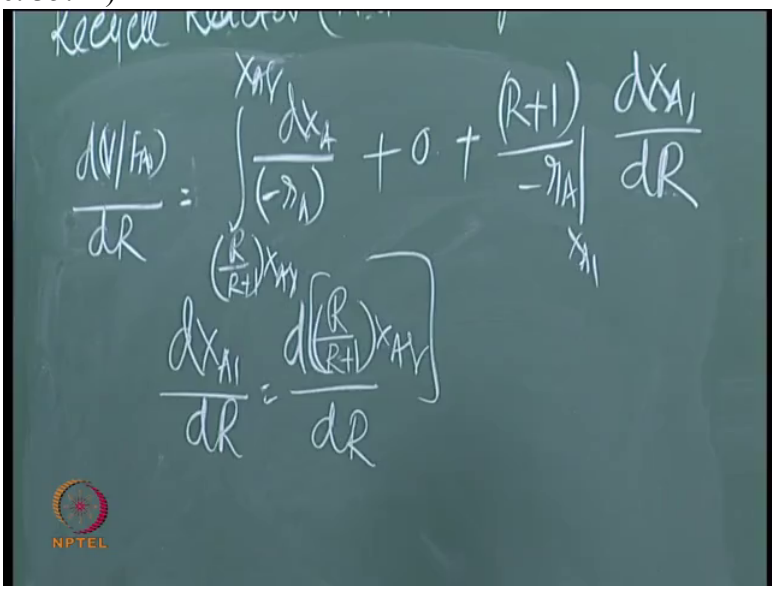

very good. This is equal to X A f divided by R plus 1 whole square.

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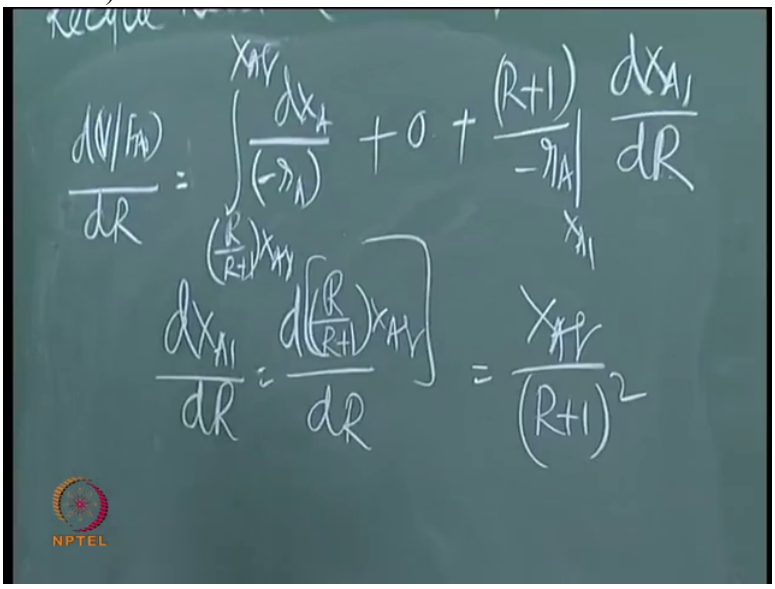

This one differentiation, very simple differentiation no, I think they are not difficult at all. Ok,

(Professor – student conversation ends)

So now but anyway I have to substitute, this is equal to zero finally, right. To be optimum. Then second derivative we can check whether we are really getting minimum or maximum, Ok, depending on the sign you will get, but this is the one.

So now there is a nice exercise of saying, arranging this equation so I will substitute here first of all, X A f by R plus 1 square. So 1 this 1 this will get canceled, so then what do I have here, this is, this one minus, no minus,

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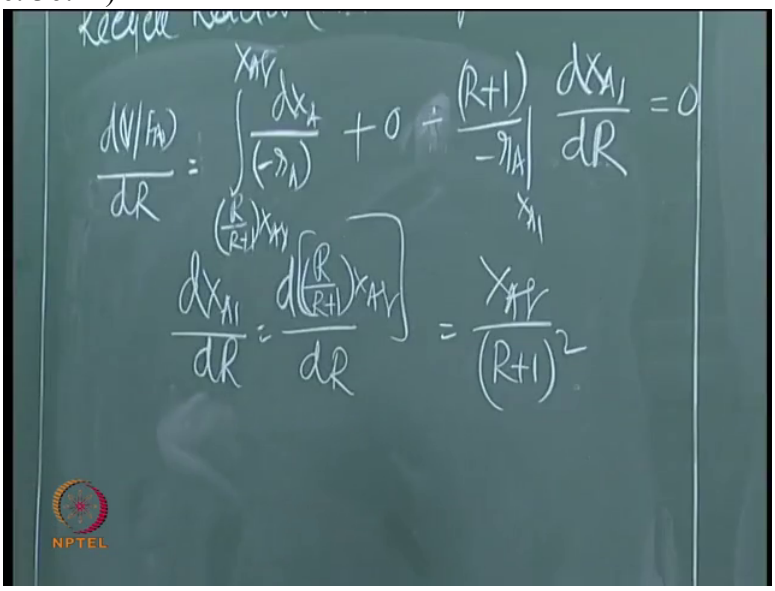

that is right , it is minus 1. He is right. Yeah this is minus, so then I have, equal to zero if I put, I am just simplifying this one, X A 1 to X A f d X A by minus r A equal to, this one is R plus 1

(Professor – student conversation starts)

Student: Minus r A plus R

Professor: Yeah this is at X A 1, this is important.

Student: That 0:36:41.9

Professor: Yeah, Ok, Ok, I am just writing again. Yeah, so how do I eliminate this fellow, R plus 1, I do not like that fellow.

Student: Intention is to

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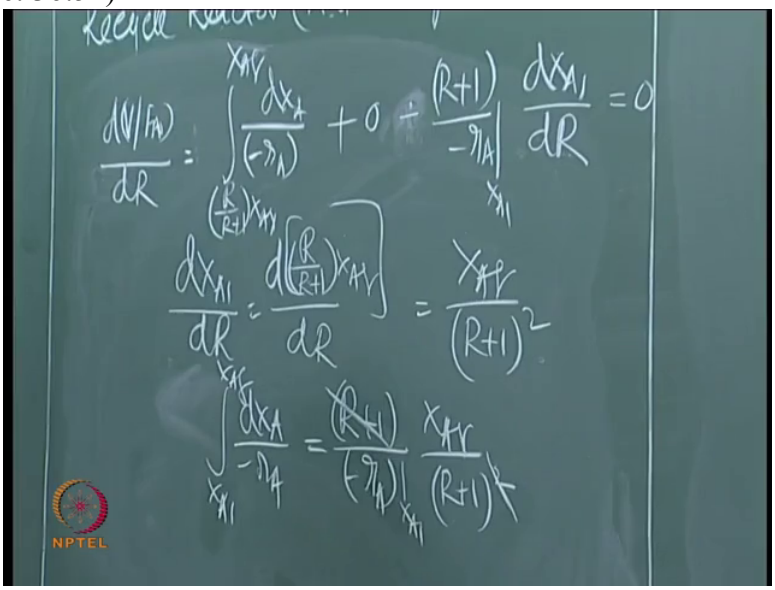

Professor: Intention is

Student: To calculate R

Professor: To calculate R but for me, to get one condition, I do not want that R. How do I eliminate that R?

Student: 0:37:06.4

Professor: Then that will give you a very beautiful condition. You have to eliminate that condition; I mean eliminate that R from the derivation.

Student: F A naught divided by

Professor: V by F A naught is coming there? Ok, I will give you the equation. Can I say R plus 1 equal to X A f by X A f minus X A 1, how? How do you say yes?

Student: The left side

Professor: Because I have written there?

Student: No Sir, X A f is equal to 1 by R plus 1 into X A.

Professor: Yeah, yeah, yeah please do that. You know I am a very dangerous fellow. This alone will be separate test. This small portion for 5 minutes Ok. So that you have to arrange that and then only you have

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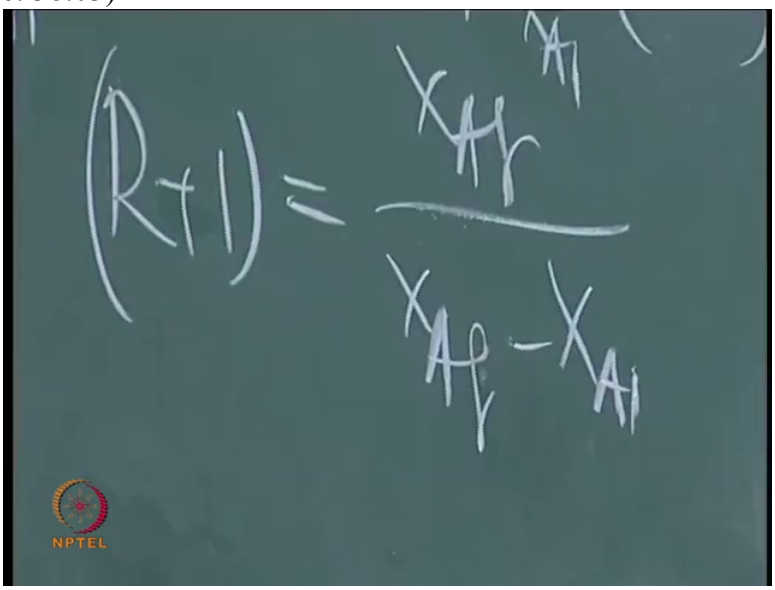

to find that, Ok, good. So now I want to now happily remove this. That means what is that I have to remove? X A f by R plus 1 now, X A f by R plus 1 equal to

Student: X A f minus X A 1.

Professor: Yeah, it won't get cancelled, Ok. Cancel means I am just taking this X A f by R plus 1 equal to

Student: X A f minus X A 1

Professor: X A f minus X A 1.

(Professor – student conversation ends)

So now the condition is if I do that, wonderful condition, 1 by minus r A at X A 1, Ok X A 1 equal to X A 1 to X A f d X A by minus r A, I am just writing this equation only, minus r A divided by X A f minus X A 1.

What is the meaning of this condition?

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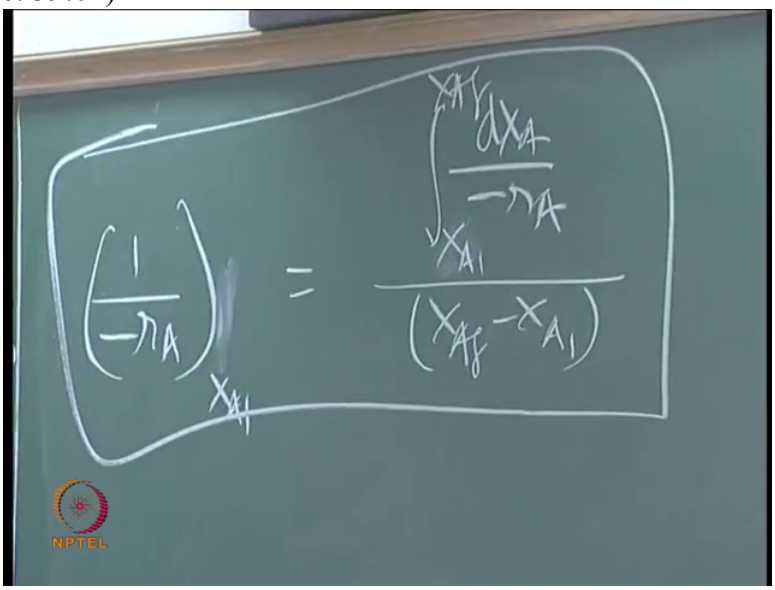

This you got no? No problem, I think. After substituting here and rearranging who can tell the physics of that, this mathematical equation? Yeah this is again you know simple calculus only. How do you find out the average of, like for example temperature varying with length? If the temperature is varying with length how do you calculate the average temperature?

(Professor – student conversation starts)

Student: Sum of all

Student: Integral

Professor: Temperature is varying along the length.

Student: Weighted average

Professor: What weighted average, how do you find out?

Student: Temperature into length divided by length

Professor: Temperature into?

Student: Temperature into that...

Student: Small, small part

Professor: Temperature into length?

Student: Temperature into that small, small parts

Professor: Yes that is sigma of, yeah, Ok, that sigma if you are able to extend up to integral?

Student: Integral

Student: Integral T d l

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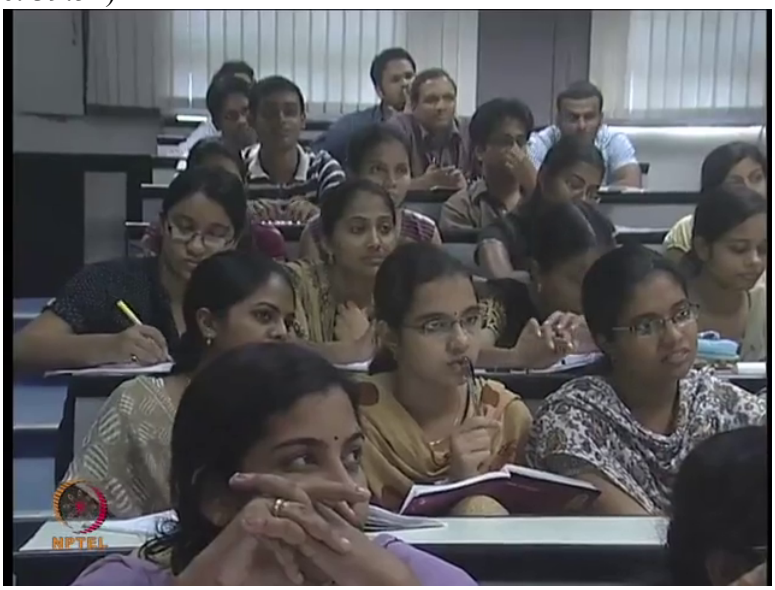

Professor: Integral T d l

Student: by Integral

Professor: Again integral

Student: That is small l.

Professor: Yes, that is l.

Student: Yeah

Professor: Zero to l

Student: Yeah

Professor: Ok,

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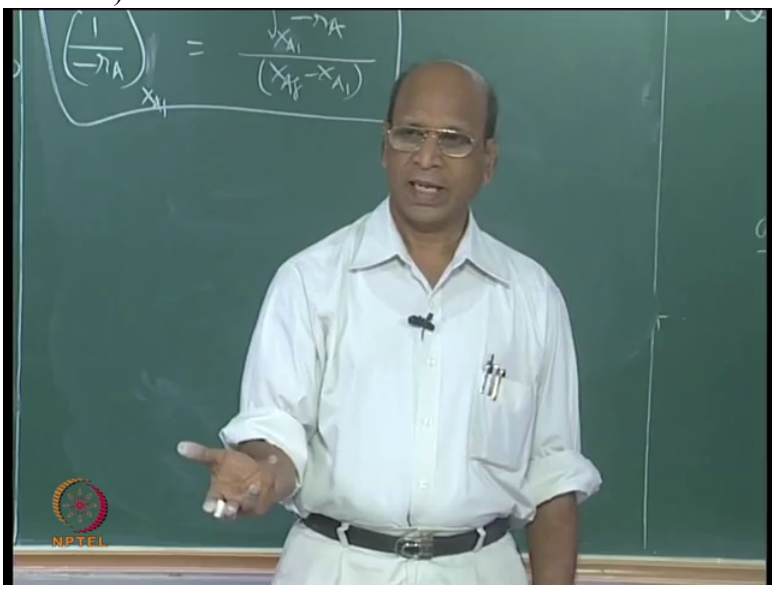

that is just, you know. We are only talking in air. But I have not written there.

(Professor – student conversation ends)

But are you; are you really familiar with that? Because this is where is missing you know, from you, not only from you, from all the students, that relationship between mathematics and physics, Ok. And this is the one average you should have done many times like exactly what he said, you know. Yeah.

Like if I have some temperature changing with length, Ok so the average temperature for example T bar, how do I calculate? Integral, yeah, so some function, this T is a function of x because T is changing along the length, Ok? So then I have d x where this is zero to L, divided by L here or simply 1 by L.

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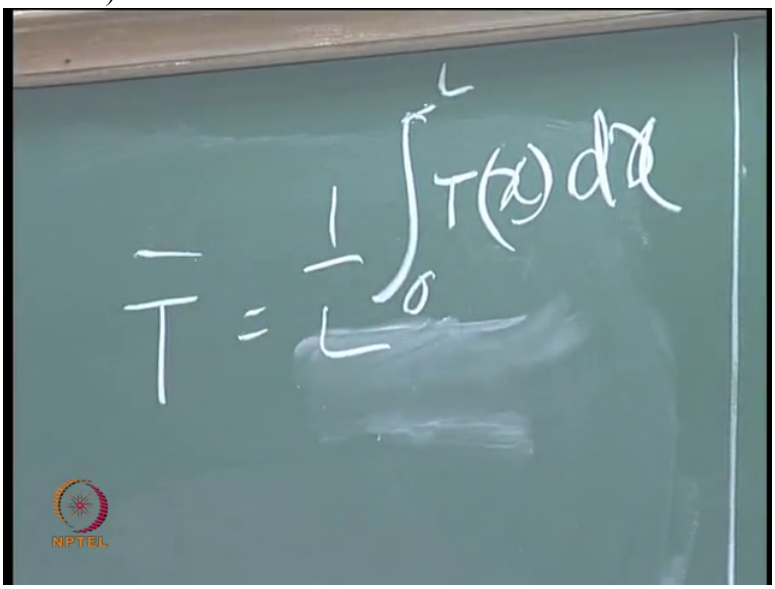

Divided by L and this is the same thing no?

Yeah, that is all; I mean that is what is exactly told here. So that means what Ramakrishna told is correct. Ok, so this condition is a wonderful condition. I think please take down the condition,

Ok. In words the above equation, I think you are writing below this no, that is why above equation, Ok. Yeah. In words the above equation indicates that the optimum recycle ratio

(Refer Slide Time: 41:32)

introduces to the reactor a feed whose 1 by minus r A value equals the average 1 by minus r A value in the reactor as a whole.

I know normally you would have written without thinking what I am trying to say, Ok. Now someone has to explain this in words, the above equation indicates that the optimum recycle ratio introduces to the reactor a feed

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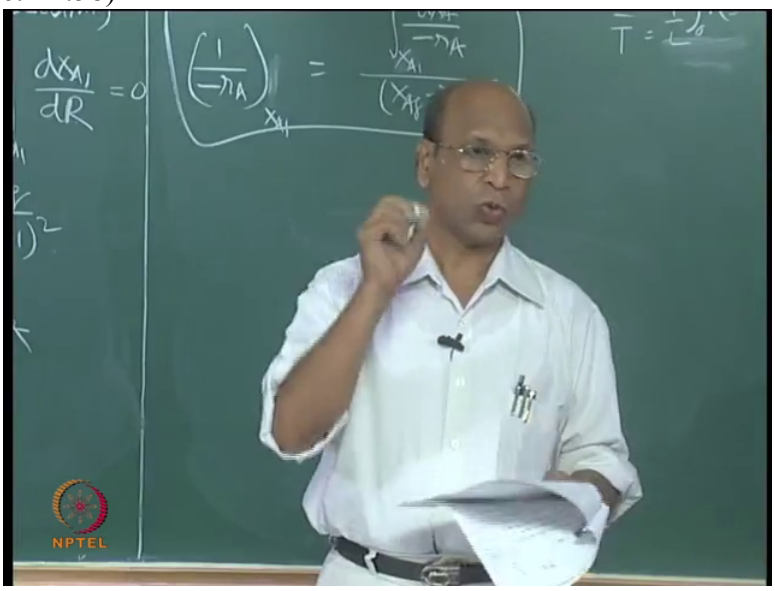

whose 1 by minus r A value, where is that whose 1 by minus r A value? Which minus r A value you are talking?

(Professor – student conversation starts)

Student: Right hand side of the

Professor: Right hand

Student: Left hand

Professor: What is, left or right?

Student: Left

Professor: Left hand side, exactly.

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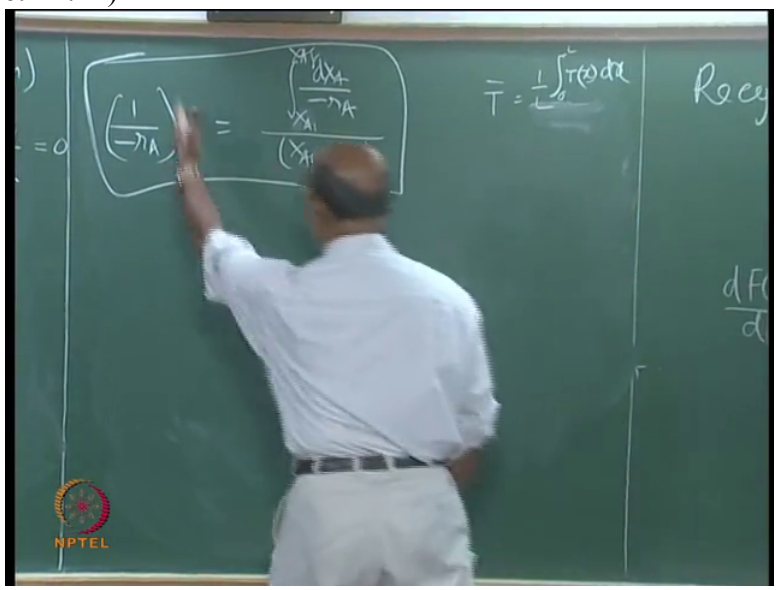

This is the rate, Ok, yeah at X A 1, at X A 1, right that is what; whose, introduces the feed value whose average rate value, average rate equals, equals the average 1 by minus r A of the

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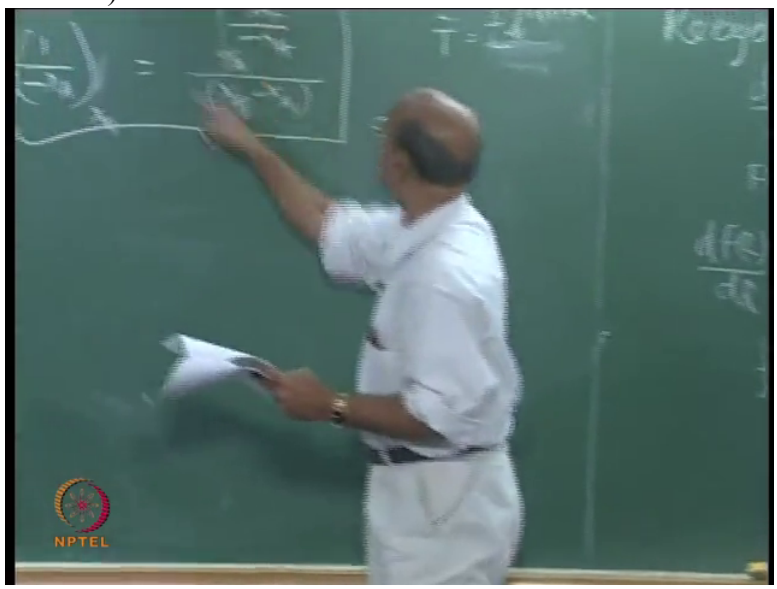

entire reactor.

(Professor – student conversation ends)

This is what, this is X A n, X A n. X A 1 entering the reactor, X A 2

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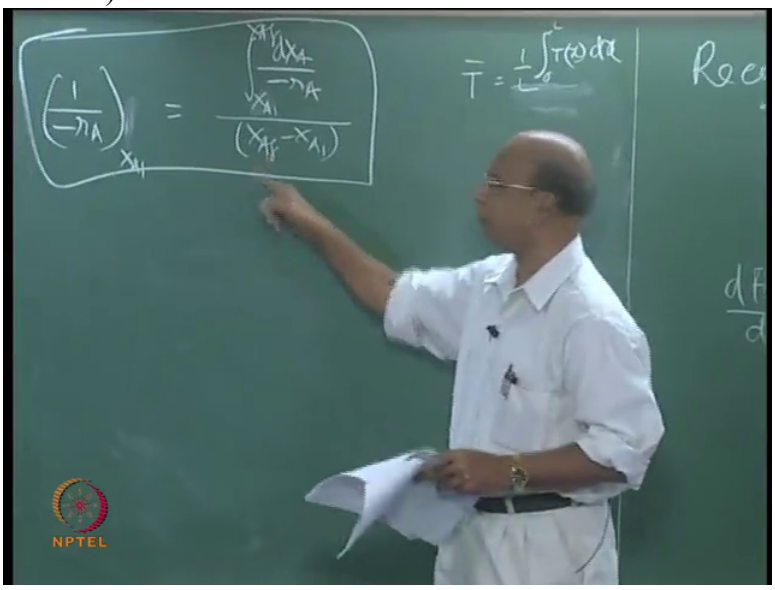

or X A f leaving the reactor, this is the average. That is for the entire reactor. So the optimal recycle ratio introduces a rate, because when you mix, the recycle ratio as well as the F A naught coming from the fresh stream those two rates must, combination of that must be this rate.

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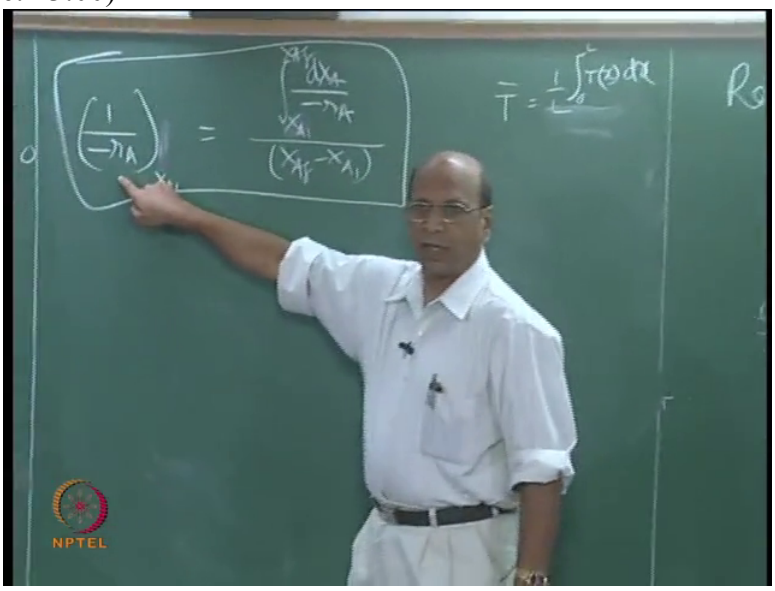

Ok,

So, because I am mixing two streams, no? So I have a rate also there, average rate. So that rate must be equal to average rate throughout the reactor. When that happens you will get the minimum volume

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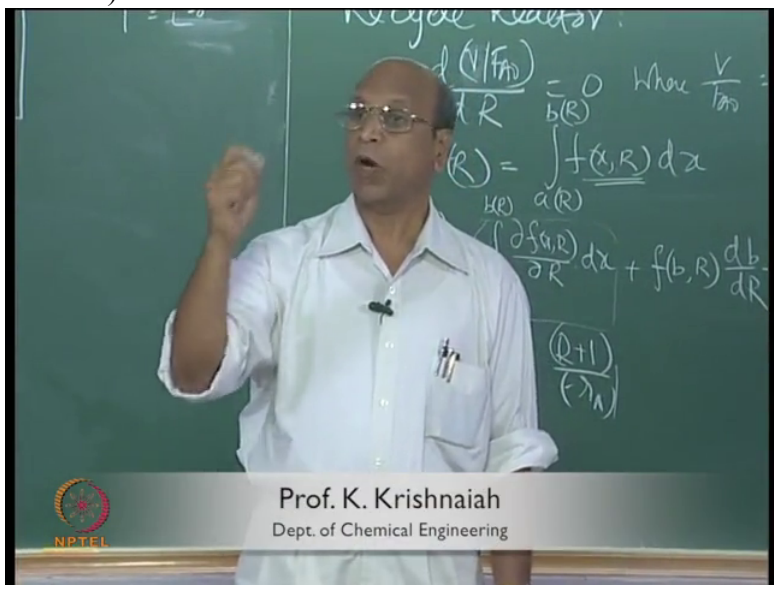

for a given conversion.

It cannot go wrong because it is mathematics,

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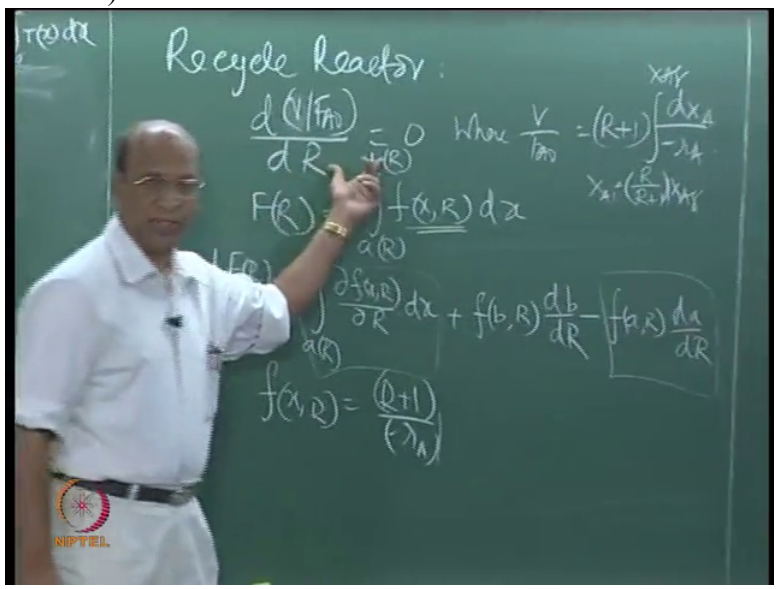

mathematical equation, because this is the first one and if you want to prove that this is really true, take the same thing, second derivative, you will get negative slope,

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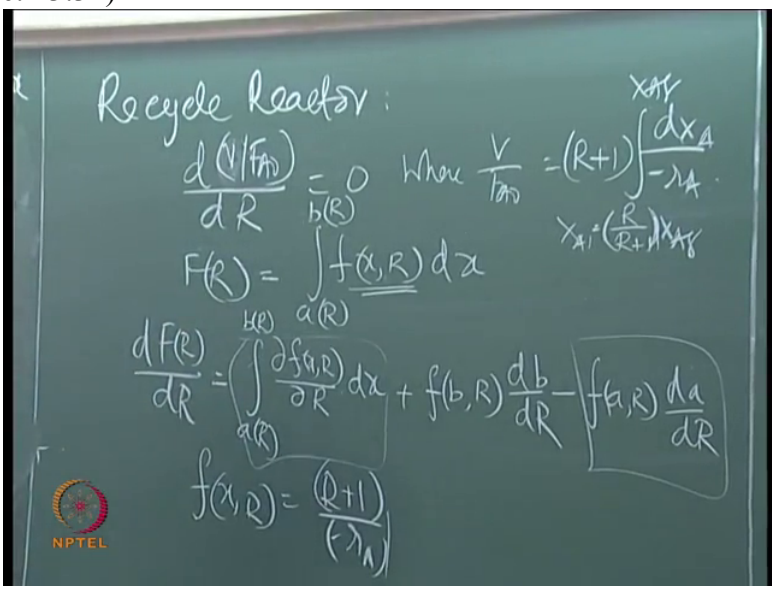

second derivative must be, positive or negative?

(Professor – student conversation starts)

Student: Positive

Professor: Oh positive for minimum, yeah right, right, negative for

Student: Maximum

Professor: Maximum. Ok here minimum volume, Ok, so that is the one.

(Professor – student conversation ends)