Chemical Reaction Engineering 1 (Homogeneous Reactors)
Professor R. Krishnaiah
Department of Chemical Engineering
Indian Institute of Technology Madras
Lecture No 13
Basics of Plug Flow Reactor Part 2

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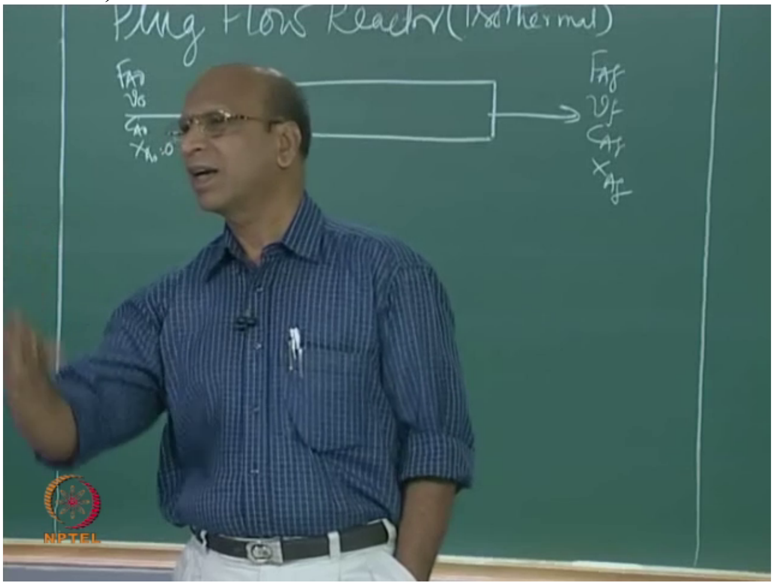

(Professor – student conversation starts)

Professor: Point 9 3 1 meter cube.

Student: 1 point 5

Professor: 1 point 5. How are able to manage different answers for the same question?

Student: (laugh)

Professor: All the data exactly same. Great I say, even science is not exact. We thought only, you know God is not exact. Because it can be described by anyone in any form. Ok, but science at least, I thought, we thought you know exactly one can define. Right.

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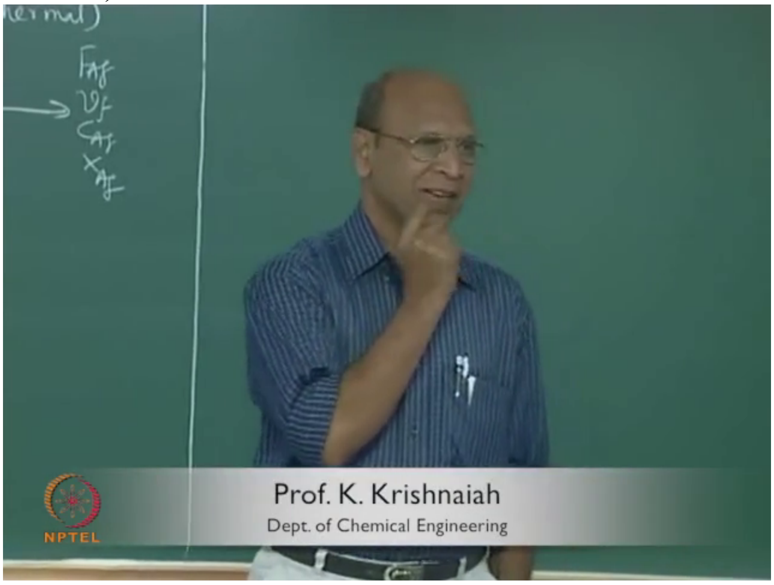

Newton's law whether you do I I T Madras or I I T Bombay or I I T Kanpur it is same. It should not change. So but here I think our problem, what is the thing, correct answer is around 7 meter cube.

Student: Zero point 6 8

Professor: 7 meter cube

Student: 7 meter cube?

Professor: Yes, yeah. So you thought it is very large value and then you...

Student: No I did it...

Professor: (laugh)

Student: (laugh)

Professor: So you thought so like that? Ok. Check again. I think you know the correct answer will be around that.

It is, of course it is slightly complicated problem, it is reversible reaction and also it is, of course the other timing and all that, you have to add. I think you will get the reaction time, how much reaction time you got, by the way?

Student: 73 minutes Sir, 73 minutes plus 30 minutes

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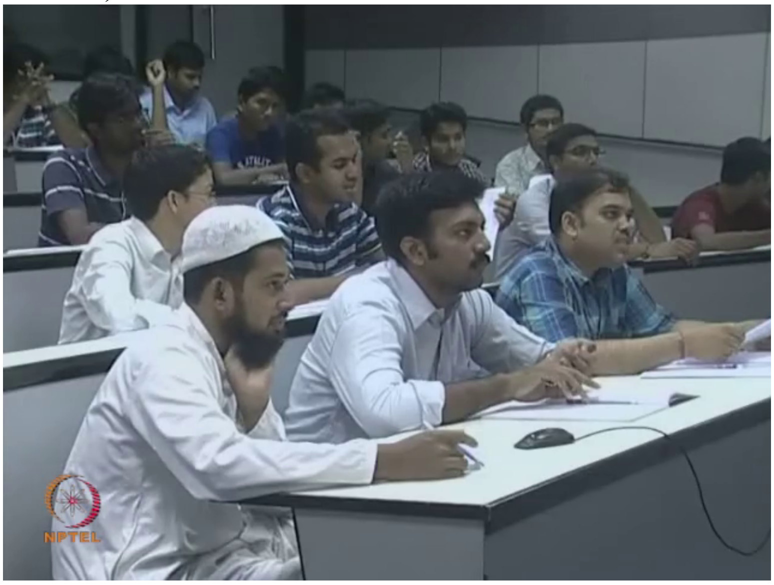

Professor: Yeah, I think around 5000

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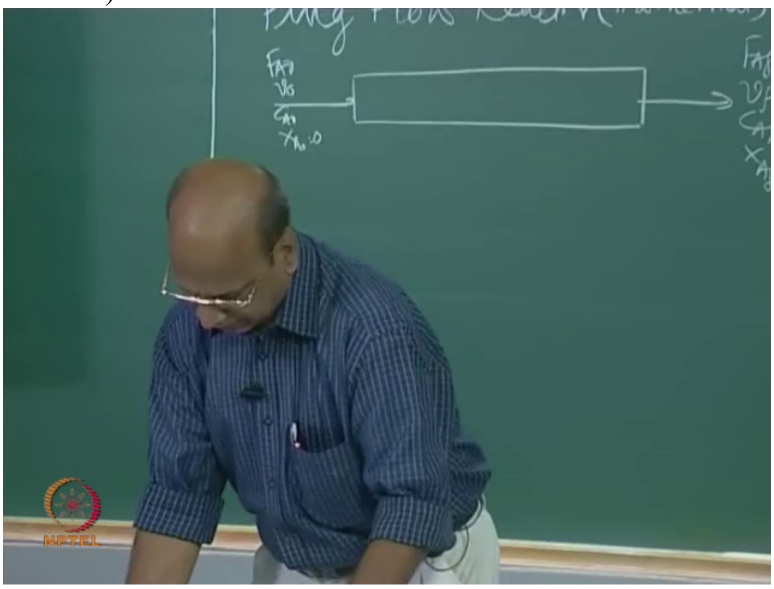

seconds is the correct answer. Yeah, around 5000, 4920, 4920 seconds. Yeah still you manage so low volume? If the reaction time is right It is only reaction time, plus another 1800 you have to add. 5000, around 5000 is Ok.

Student: 5000 reaction time.

Professor: Yes?

Student: 5000 reaction time.

Professor: Yes, maybe I think you know, that other values slightly this way, that way, yes? Yeah and then you have to add that

Student: 30 minutes

Professor: 30 minutes means 1800 seconds or you can convert that into minutes and then add. So then divide the total production rate, number of batches and per batch, that is all, correct no?

Student: Sir, how many number of batches?

Professor: How many number of batches?

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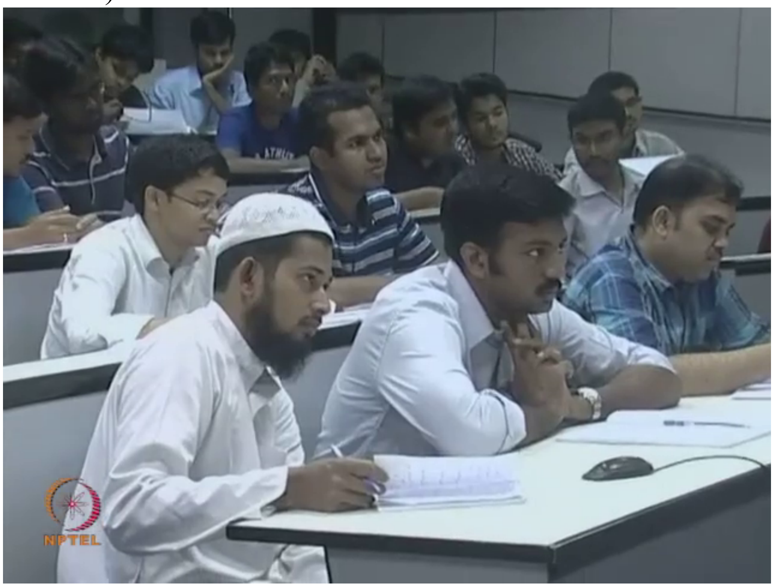

Student: It cannot have 7

Student: It is too much, Sir.

Professor: What do you mean by too much? Around 13 batches, yeah

Student: You are right, 13 batches.

Student: Then it becomes up to 100 tons per day, Sir. That is, answer should be..

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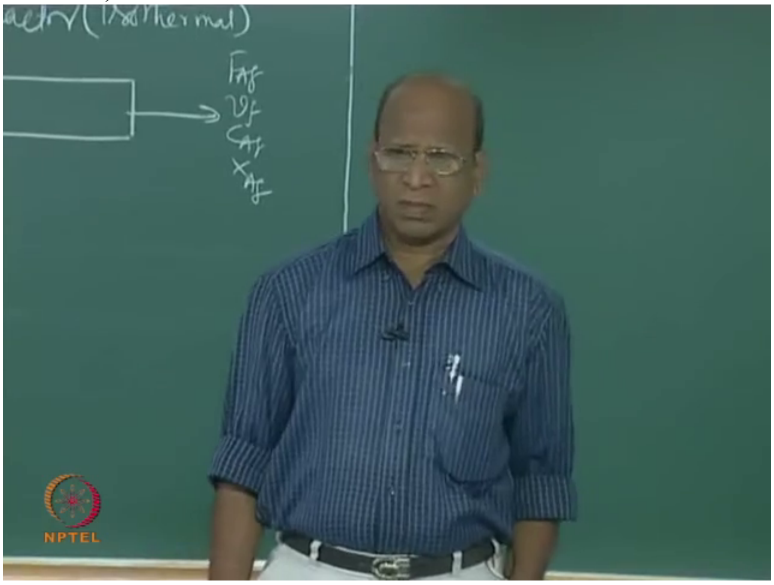

Student: Zero point 7...

Professor: No, you have again that 30 minutes going and all that, no?

Student: 0:03:07.8

Professor: Yeah, so but I think that is the one. 7 meter cubed, around 7 meter cubed you will get, may be 6 point 9, 6 point 8 like that. Try again. But the reaction time is right. I do not know how you calculated other things. Ok, reaction, mixture density also is given. Where do you go wrong? It is, you know, probably you would have gone wrong where you have C A naught equal to, is not equal to C B naught in this case. Ok

Student: 13 batches also I got. But value I am getting point 7.

Student: Point 7 4 I am getting.

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Professor: You got, anyway but others I think, others also you try. I think many people, I think, I know only 10 people

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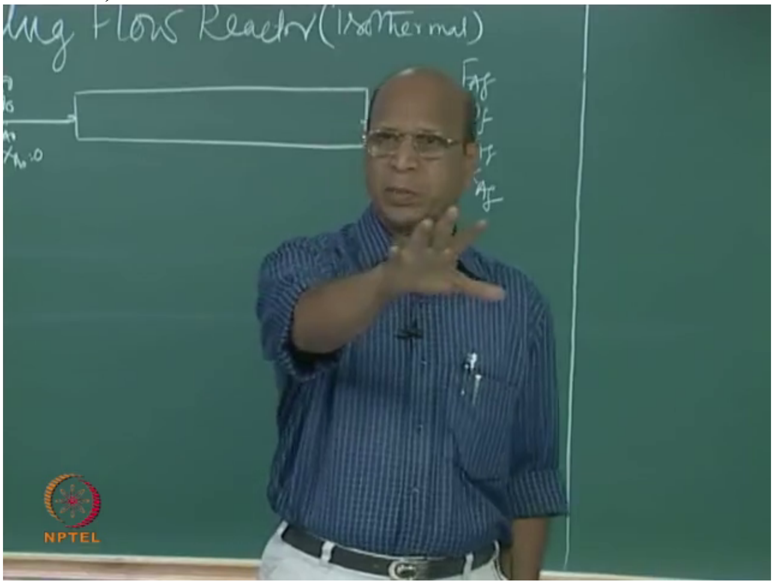

would have done. The remaining other people would be only watching. Ok, I think you also do and let us discuss later. Ok. So I got around 7, may be wrong sometimes, alright. Around 7 meters.

Student: Point.

Professor: 7 meter cube. Ok. Good. Yeah I think now come to the class, the present class. Plug flow reactor, right?

(Professor – student conversation ends)

We have been discussing about the concept of plug flow reactor and you know, I asked you, can you write two concepts in C R E? That is one of the, that is the last question in that zeroth test, the first you know, the first day when I gave that test. And there was no answer. This is one of the concepts.

Concept means something you imagine in your mind and then based on that you develop all the equations

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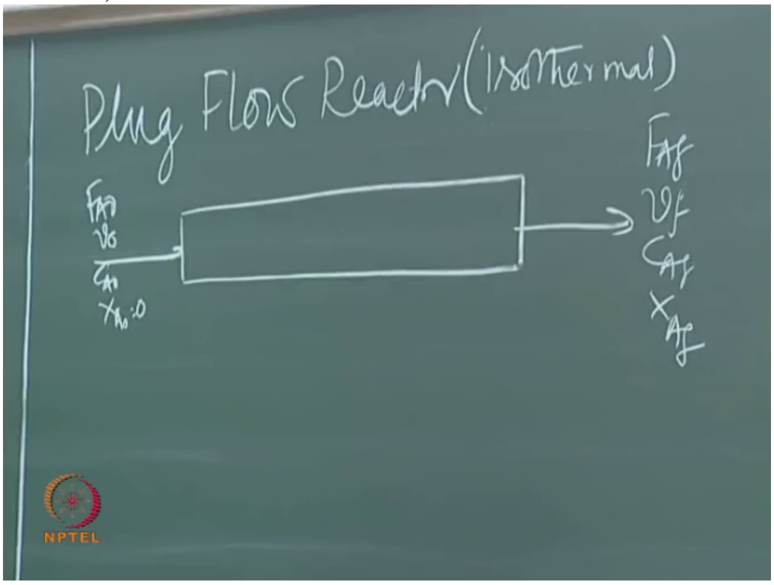

and now try to find out whether you have your original,

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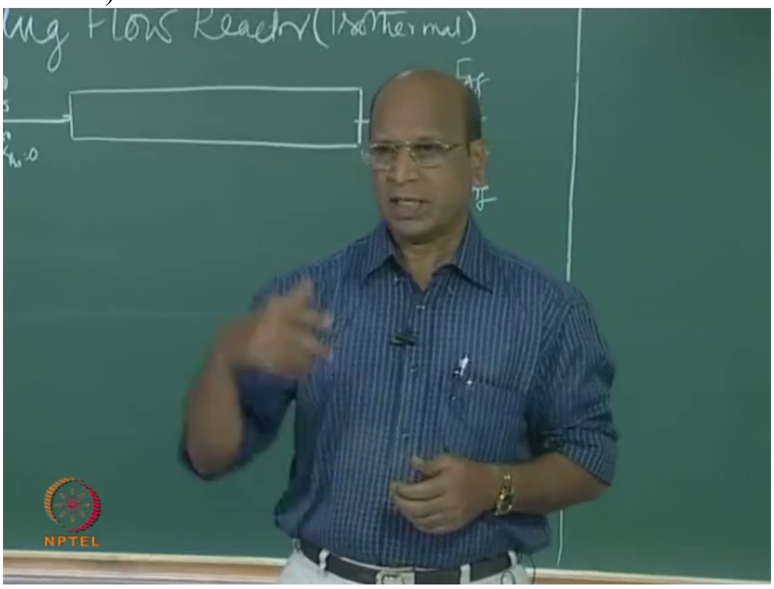

I mean assumption and actual calculations whether both are same or not. If both are same then your concept is right. Right?

So this is one of the concepts in chemical engineering. And this is beautiful concept, plug flow. Why it is beautiful, I will tell you little bit later. And we told that the basic definition of plug flow is, tell...

(Professor – student conversation starts)

Student: Flat velocity

Student: Time spent by each molecule ...
Professor: Yeah time spent by?
Student: Time spent by molecule is same.
Professor: Each molecule is supposed to be same, so then automatically you should have flat velocity profile. Now I think you have a feel what do you mean by axial mixing.
(Professor – student conversation ends)

Axial mixing is pushing people in the queue, backward and forward Ok, like that even in the reactors, because of the turbulence and you should not confuse with turbulence and mixing. The turbulence in pipe is very, very limited in the sense that it is only velocity fluctuations where we take them as turbulence.

Whereas mixing also, though that there is turbulence, but mixing is a big chaos. Mixing occurs throughout the equipment where as in the turbulence when you have a pipe and then, you are talking, I am talking of pipe flow, Ok, very clearly we have to distinguish that, because we have two extremes. One is mixed flow reactor, other one is plug flow reactor.

So in our plug flow reactor when there is a pipe and then through which the flow is going then the turbulence what we are talking is velocity fluctuations. Now you can go and see McCabe Smith's book or some other Fluid Mechanics book where they nicely show only small variations in the fluctuations of the velocity.

That fluctuations are not allowed now for plug flow. Even that fluctuations are not allowed. Right. So that means molecules enter exactly like flat velocity profile without any fluctuations. It will move and now the reaction depends on how far it has moved and you know the total length we are

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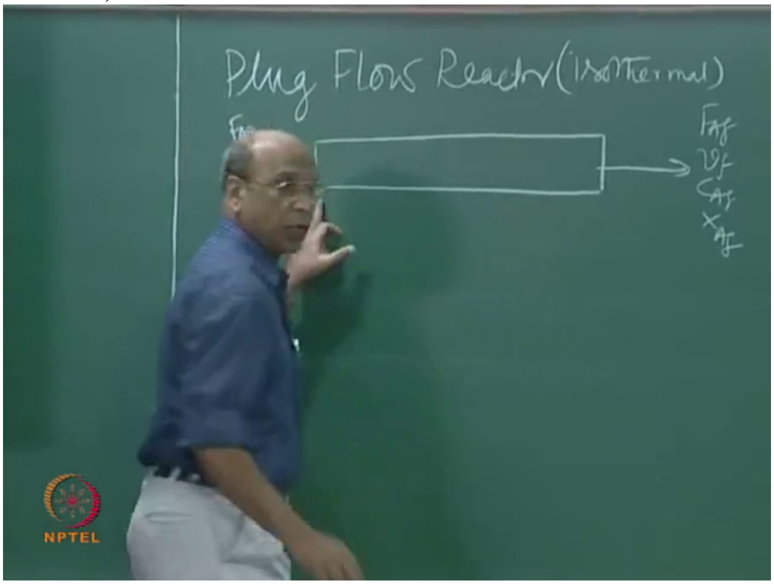

providing for the reaction to take place.

You, let us imagine that you have provided 30 seconds for 99 percent conversion example. So around 10 seconds you will be in one third, then the reaction,

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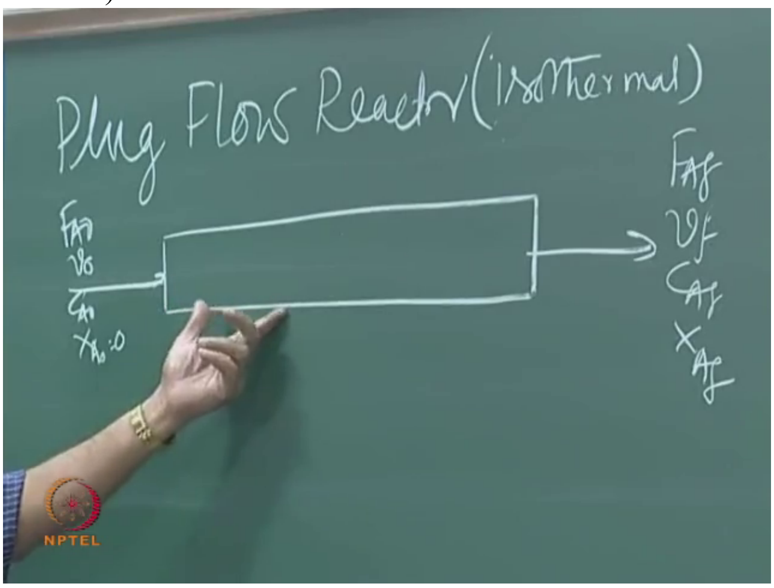

I mean the conversion will be, not exactly one third here, it is not linear. Ok, conversion cannot be linear, depending on what kind of reaction you are talking.

So that is why here you will have some conversion. Then afterwards again you will have some conversion Afterwards again you will have some conversion. But when I look at the cross-section you will have the same concentration at that cross-section. That is why we say we have infinite number, sorry yeah infinite mixing

(Professor – student conversation starts)
Student: Radial
Professor: Radially. And all of you would have assumed, you know, definitely, yeah I think for your GATE examination also you would have, you would have prepared that infinite number of tanks giving you plug flow, Ok.
(Professor – student conversation ends)

Really did you understand that concept? Mathematically you can prove it, Ok. But really, has it gone to your blood? Once it goes to blood only the concepts will be with you all the time. Ok. Yeah. What is our assumption? In the assumption itself, we have that definition; of infinite number of tanks giving you plug flow. Just in assumption itself. But we never go deeper into that assumption, correct no? So what is the assumption? At any cross-section you have

(Professor – student conversation starts)
Student: 0:08:14.4
Professor: Infinite? Mixing. When do you get infinite mixing? When you have one perfect mixer. How many cross-sections you have in this?
Student: Infinite
Professor: That is all. That is why infinite number of tanks.
(Professor – student conversation ends)

Also when you calculate, you know, for 90 percent conversion plug flow is this much. Sorry. For 90 percent conversion, plug flow is Ok. For 90 percent conversion mixed flow reactor is giving some volume, right? Now you want to use number of tanks in series. Ok.

You calculate for 1 tank, volume for 90 percent conversion. It will be much, much larger than plug flow. Then you take 2 tanks. What will happen to the volume? Decreases Ok, to some other...that also we will do one example later. Then you take 3, further decreases. Then you take 10. It becomes very small.

When you go to infinity that will be equal, volume size will be equivalent to almost zero where you are defining what is radial length, yeah transverse direction radial length. I mean that radial dimension. See how simple it is. I do not need any mathematics for that. Ok. This is favorite, I mean topic for many examiners also to be given, prove that infinite number of tanks give you the plug flow equation.

You take first order and then write you know, some equations and then try to prove it. You do not have to prove it really. If you, of course, mathematically. There are still some people who will not believe words. So that is why for them mathematics are required. So then you go for mathematical proof and say that yes, what I imagined and what I also mathematically proved, both are same.

You see how simple it is to remember now? Very, very simple to remember why infinite number of tanks would give you plug flow. It is in the definition itself. Normally we do not think beyond assumption of flat velocity profile. Some more things if you, a little bit, you think a little bit more then it will be radial direction mixing equal to infinity, and axial direction mixing equal to zero, Ok.

So but I think I may give in the examination, prove mathematically that infinite number of tanks will give you plug flow. That is different, Ok. That is mathematical, examination. But the concept wise, very simple to do that. Because I am taking sufficient time because the entire reaction is, reaction engineering is based on only 2 reactors.

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Out of that the second assumption, you know the mixed flow assumption is very simple,

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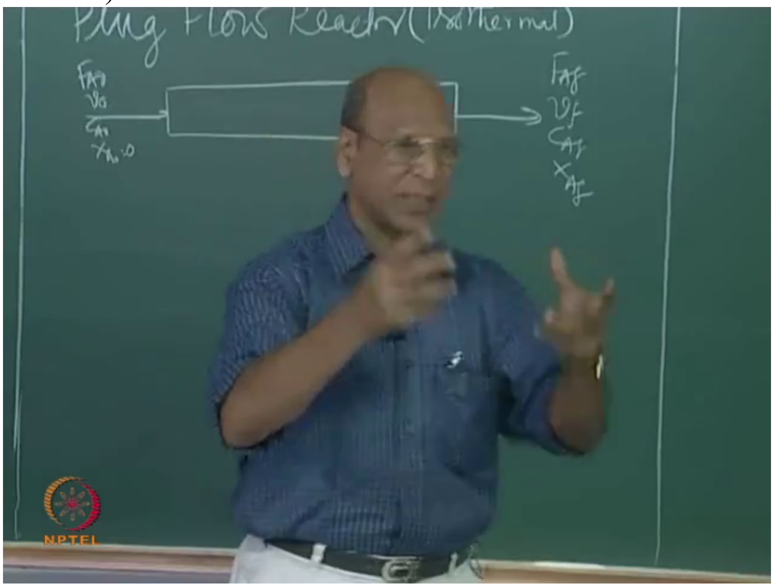

for easy imagination. That is very simple. Where as this one is not that simple. Like parrot we repeat. Because my teacher repeated it must be flat velocity profile, I will also go and tell that it is flat velocity profile. Fortunately or unfortunately if you become teacher then you also tell the same thing, flat velocity profile.

So like that, generations to generations it goes as flat velocity profile without trying to understand what is real concept. Why? Why this flat velocity profile should be for plug flow? Because idea is that each and every particle must spend exactly same time. For that all these definitions are required, flat velocity profile, and axial mixing equal to zero, radial mixing equal to infinity, all these things are required, right and then we also have other extreme,

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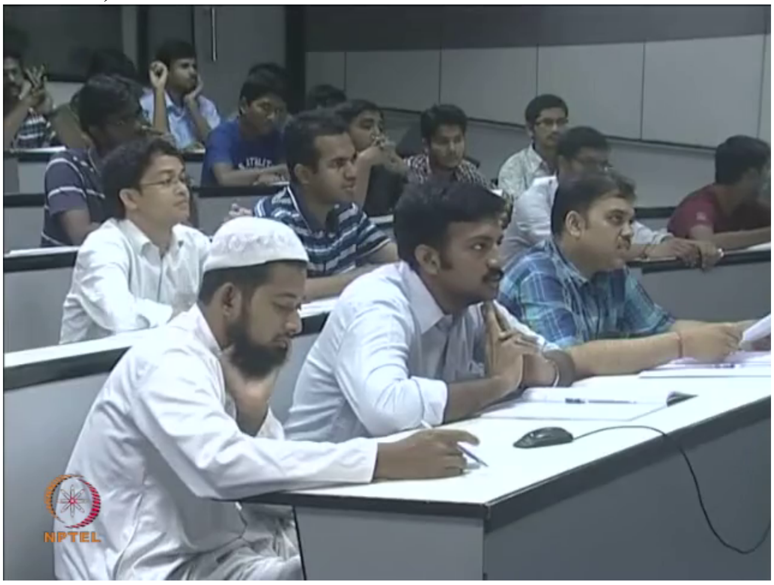

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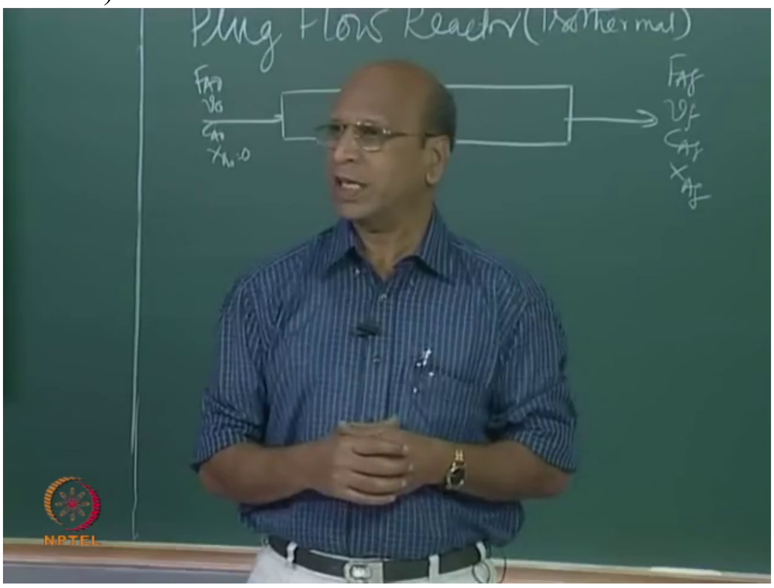

G E Davis is grandfather of chemical engineering. Ok. Another his cousin, his cousin was this Arthur D Little.

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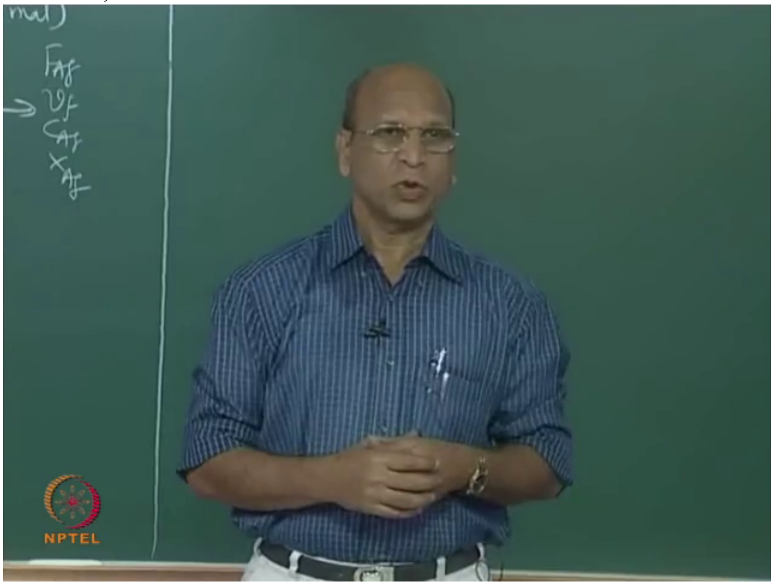

So that is why you have to do that. That is only your interest. I told you there is no description of real pleasure in learning. We cannot tell in words. I told you, no there are few things which you cannot tell in words.

Yeah, so that is why this joy of learning is totally different. I mean you cannot express in words,

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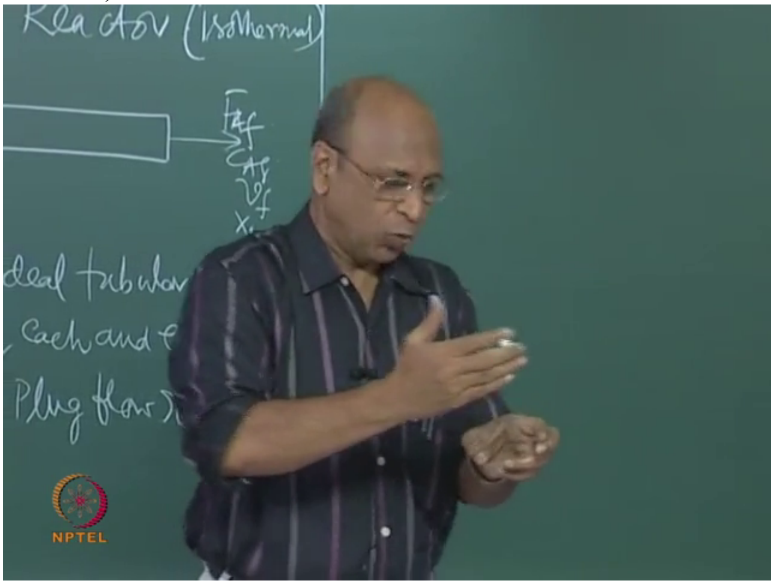

joy of learning. And the moment you have that kind of learning in you, you should not get arrogant. But I think you will be happy with yourself. Others may not be happy that much but you, yourself are very, very happy if you know many things.

But that should not go into your head and then you should not belittle others, scold others and all that, Ok. But still that gives you, that is why, I mean every God must be like that. But we see you know lot of movies and many movies are there in Krishna, on Krishna, Ok. I told you no, I am not particularly religious on anything, I do not, all are equal for me. But example I am telling.

So He knows what is going to happen, I mean at least in the books, what is going to happen, what has happened and what is happening. So that means he has got all the knowledge. And you can see him, how? He will smile also very carefully. You can see that, you know.

That smile will not be laughing like any ha, ha, ha, He will never. Krishna will never. Ok because other people will laugh like that. Duryodhana may laugh like that. So like that you know every time, you look at Him. He, you know, you look at Him as if He is very, very pacified person. Very calm.

Like that I think any, any Gods, at least we imagine Gods, yeah any God's history if you read all of them must be like that because all of them understood what is going to happen, all the knowledge what they have. Ok. We are only trying to draw some fraction of it, one millionth of it, one billionth of it from that source, if you imagine, I mean if you really, truly believe God.

I believe Nature. That is why what we are learning is all from the Nature. And the entire research is only to crack Nature. Just to find a small thing of what is happening. How clouds are forming? Big problem, you know big research problem, how they move, why that shapes, they are not beautiful circles, or beautiful triangles or rectangles, no? All different kinds of shape.

And you look at a cloud and then just imagine that it must be a beautiful girl, it looks like beautiful girl. Or again you look at that and say that it must be a beautiful bird, then it looks like a beautiful bird. Because by the way, we always say beauty with girls. We never say with boys. You know the reason?

I think, on this planet it is totally different, human beings are totally different. If you take any animal, male is very beautiful. Only in humans reverse happened.

(Professor – student conversation starts)

Student: (laugh)

Professor: Ok. No really. See peacock for example. Male peacock is very beautiful. Lion, that male lion is really wonderful to see, you know that magnanimity and that kind of, the moment you look at that, Oh my God, lion! But if we see again female lion, you do not feel that. Every day you may be seeing, no? Any animal which cannot see without the aid of light in the night, they will happily sleep after 6 o'clock. The moment dark comes. But that is the only time we start working.

Student: (laugh)

Professor: And we are also same, on this planet the life is same. Life cannot be different because all the species have come on this planet. There are some, I think 90 percent of the species daytime, sunlight only they take food and then they do not do any job anyway, they search for the food throughout and once they have sufficient food, then they want to propagate their own species. And then that is all. I think male, female will join and they simply propagate their species. That is all. You are chosen on this planet only to propagate your species. If you allow the humans I think you know they will really pollute very fast. Ok, so that is why I think all other restrictions are there in China, only child and India it may come half child or something like that sometime.

Student: (laugh)

Professor: Because we are crossing China. Ok. But I think you know, naturally they will control on their own. In other species. Right?

(Professor – student conversation ends)

I do not know whether you heard the name Aris, Rutherford Aris, Ok, has anyone read his book? You read. I will give you Nobel Prize if you really understand that. Ok, really I think you know, very, very complicated. He has written same Levenspiel information in terms of mathematics.

But if you understand these concepts and go to Rutherford, I mean Aris book, wonderfully you may understand. But his mathematical knowledge is fantastic. I think even for conversion he uses the term zi, where for most of us we do not even know how to write this. You see, like this.

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That is zi. Zi is the conversion for him. We write simply X A, like this. What you call that, zi only no?

(Professor – student conversation starts)

Student: Epsilon

Professor: It is not epsilon. Epsilon is only this. Epsilon does not have tail.

Student: Is it zeta?

Professor: No, zeta is again different. It goes like this.

Student: Zi?

Professor: No, they also, that capital form and also they also have small form, Ok.

Student: Capital...

Professor: Yeah, so they have I think, this is zi. So that kind of complicated. But I think he is very stable, very good. And he writes poetry. Poetry comes when your mind is stable, please remember that.

(Professor – student conversation ends)

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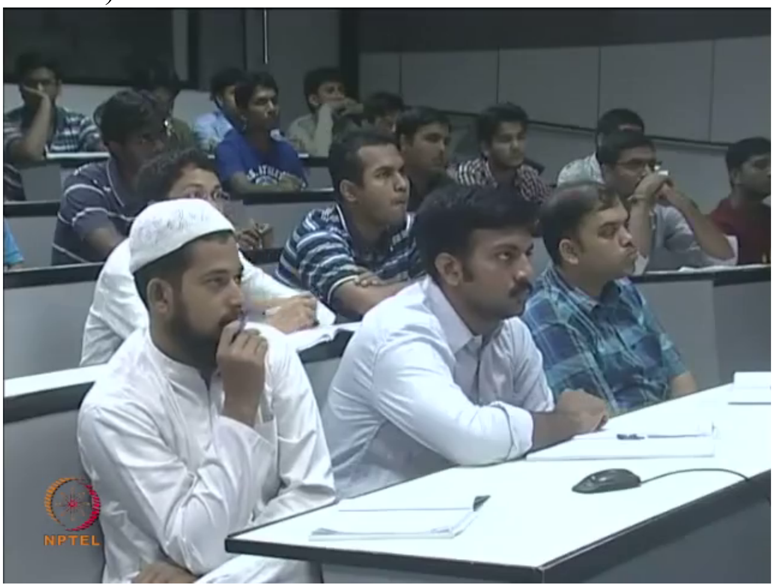

Anyway, so. Yeah coming back to that, that is why

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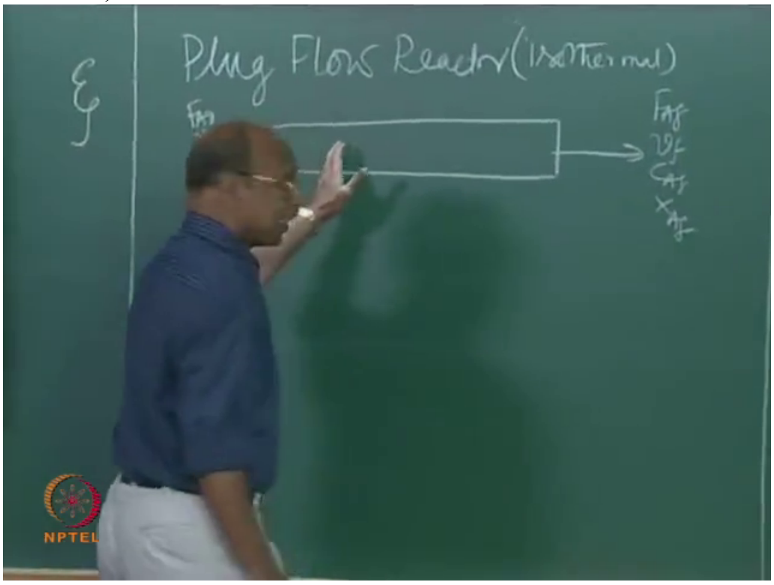

I told you no, all this started because of the pleasure in learning. That you have to taste. The moment you taste yourself, you cannot come back. We will say that you have that nectar, no, amrut, yeah this will taste much more than amrut.

This passion for knowledge once you start, enjoying the happiness of learning. Really I am telling you. You just try that. I do not know, even if one tries I think, I will be very, very happy. So that is why. You know our time is limited during our education, right. So we will have only…

In the school you will learn something. But you won't understand. Ok in the university, you learn also but with understanding you have to do that. Then when that understanding comes, automatically fantastic. Really very, very happy! So for that, only thing is you have to read, read, read and then try to

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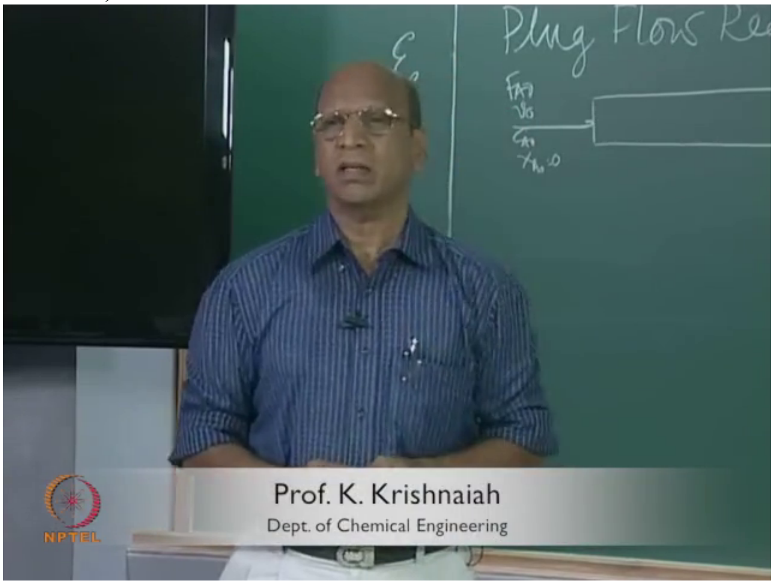

understand, that is all.

If you are not able to understand, ask friends, ask people, ask teachers all that. And you should not feel bad you know to ask anyone if you do not know something. If I do not know how to add 2 plus 2 equal to 4, that means really I do not know that. So that means why should I feel bad? I can happily go and ask.

That is why each and every individual is different. My learning capacity is different. So you would have easily understood 2 plus 2 equal to 4, I would have not. But because I should not compare with you and then go and say, that no, no, no I think I cannot ask because people will laugh at me and all that, you should not. Because each individual is different.

We will say that Ok, after first class you should remember this, after second class you should remember that? After chemical engineering you should remember that or mechanical you should remember that. These are all our own limitations what we put. But brain will not accept that. That depends only on your capacity of learning.

For that, and one beautiful thing with brain is anytime you can learn. I think even a person about to die, ninety years, if he is interested in chemical engineering, he can still come and start with what is chemical engineering and all questions and then he can learn. Brain accepts that. It is not that beyond certain time you cannot learn. So that is the beauty with brain. That is beauty with nature.

Anytime you want to learn you can learn. Not only we, any species. Otherwise you would have not survived. If that learning capacity is not there, learning capacity does not mean that getting degrees. Yeah, learning capacity is you know, trying to observe with the nature and also go along with the nature and try to escape nature if there is, for example, there is a tsunami or there may be explosions or there may be what this, they, lava and all that comes, you know.

(Professor – student conversation starts)
Student: Volcano
Professor: Volcanoes, yeah all these.
(Professor – student conversation ends)

Because all species run the moment they see lot of lightning and also thunder, right? Yeah, so that is also a learning. No, no, no. I do not want to learn. I will just stay there even if thunder comes means you will be charred. That is all, no. you will become carbon, element 12 with C, I do not know periodic table what is the position,.

Ok anyway, I will give you one more

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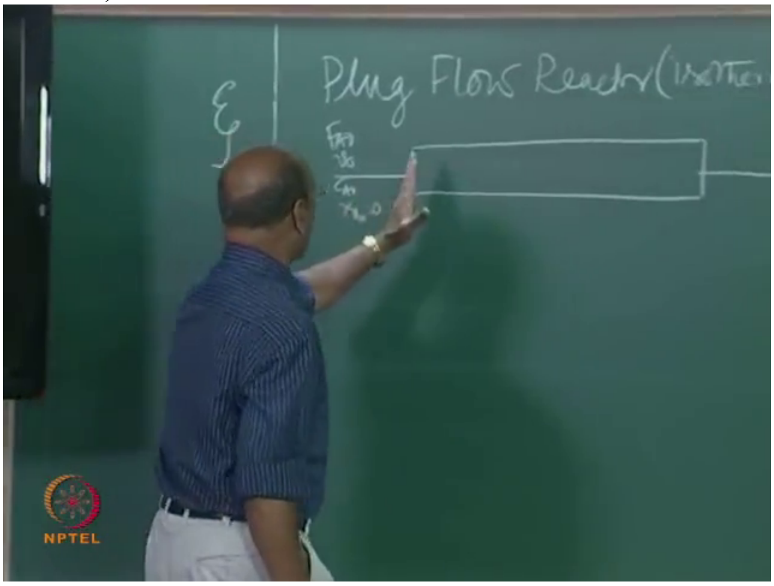

concept here to remember so that you will not forget what is plug flow. Definitely most of you would have done residence time distribution, Ok, so now we say that each and every particle should spend exactly same time, Ok.

So now if I introduce here

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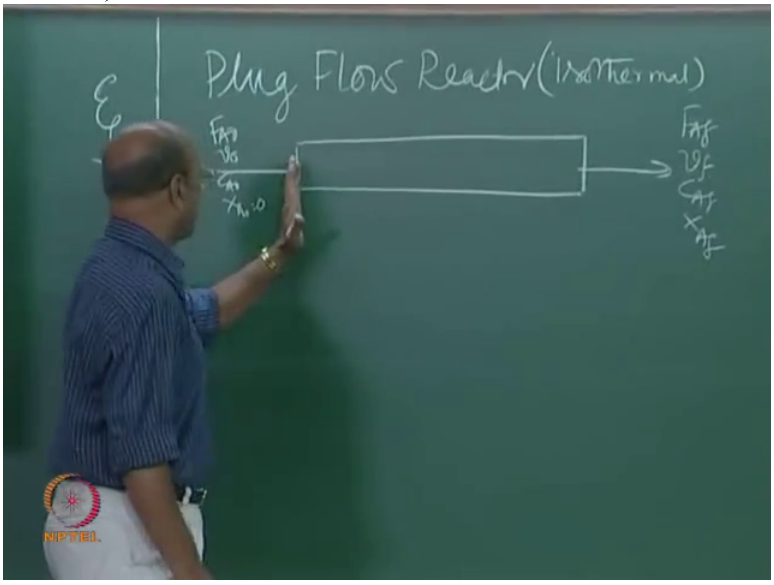

some color so that I will also see how this color is spreading throughout the reactor, plug flow reactor. So what I do is, I have various ways of putting this color.

One way is, just imagine I have a tube, 4 inches tube and then I take a disc of color, you only remember our C D disk, I am not talking about the Hard Disk, Ok, hard disk has got another meaning. Ok, C D type you know, very small thickness, red colored one, this is white color, this is water which is flowing and suddenly

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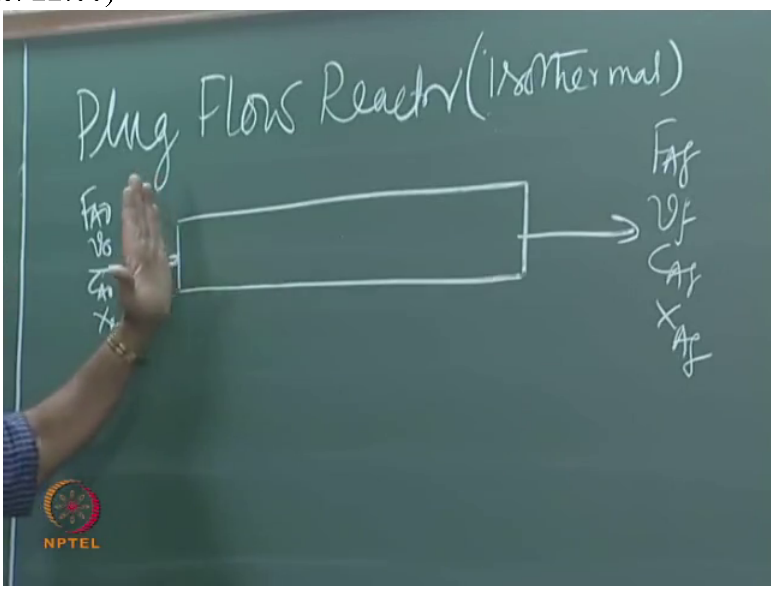

I would like to introduce that red disk inside this which is totally soluble. It is soluble, it is not hard disk, that is what I was telling, Ok.

So then and I know that the total time is 10 seconds. How this disk moves inside the,

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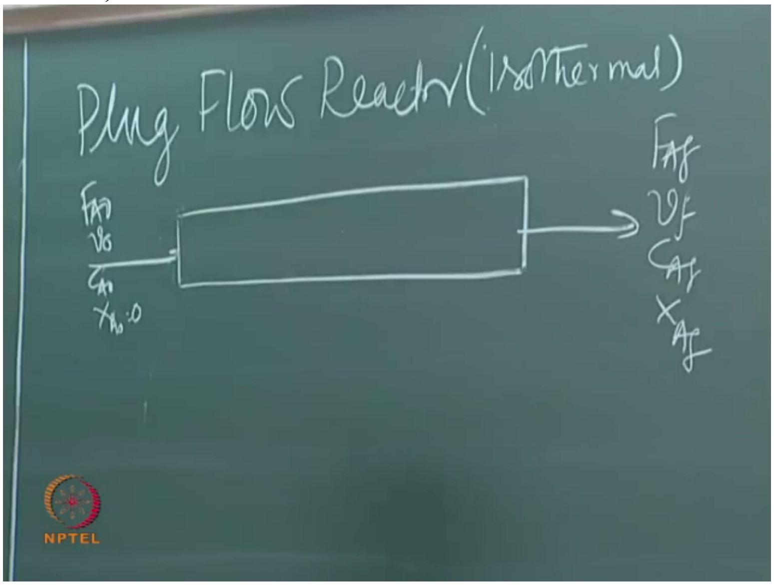

you know water is continuously flowing. By somehow, it is only imagined experiment, by some imagination, I will just assume that, Ok, disk suddenly entered the cross-section entirely fitting there, exactly fitting there. It is uniform cross-section. Even though I have written slightly bulked here, bulk there, I think you know it is exactly same cross-section. How does that move? Moves as?

(Professor – student conversation starts)

Student: 0:22:45.9

Professor: What, sorry? Not able to imagine? Able to imagine no? Because this is water flowing, just imagine that a small thickness of that flow has become suddenly red. How does that move? Yeah, Sushmita you were telling something. Moves like what?

Student: Moves as a disk only.

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If it is ideal...

Professor: It is ideal only we are talking about. How does it come out here?

Student: As a disk.

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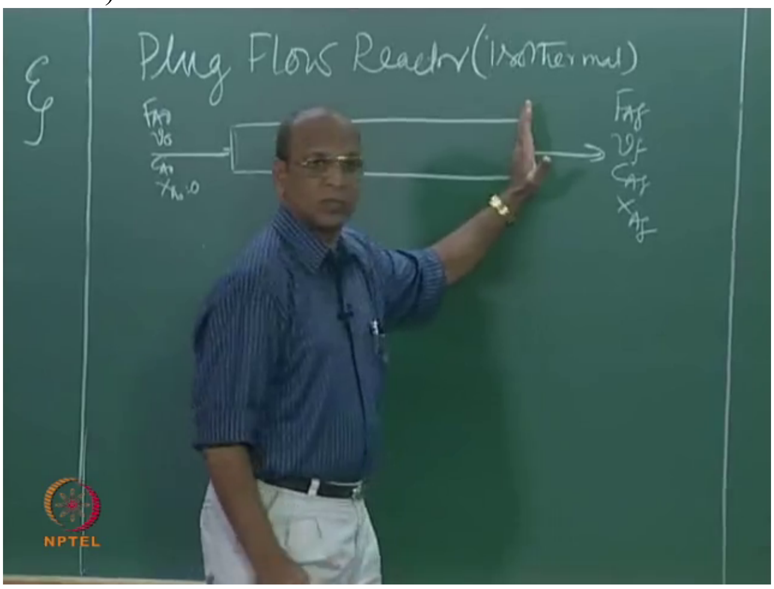

Professor: Exactly as a disk.

(Professor – student conversation ends)

That is a reason why, when you have, it is equivalent to your direct delta function, Ok. That is what is called pulse input, pulse input. Suddenly you introduce the pulse and then observe at the end how did you get this pulse, right?

So even if 50 percent of the time, if you look at the midway,

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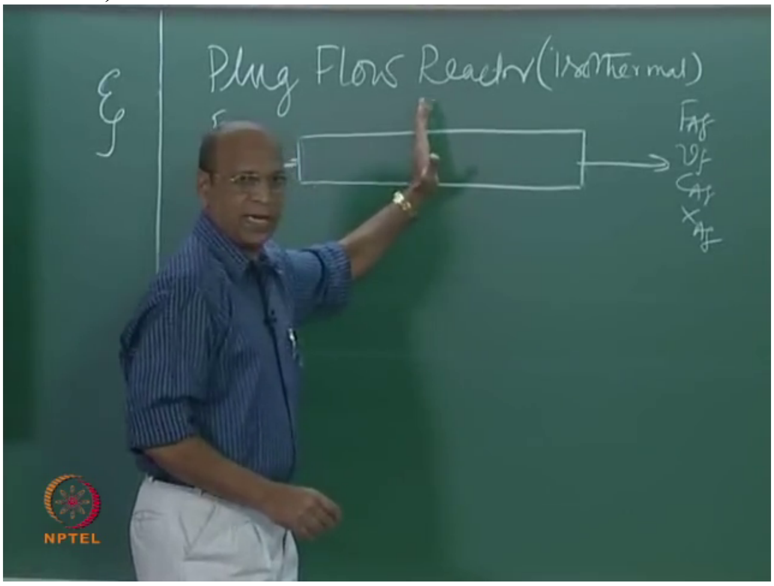

then exactly you will see that red disk and here it comes. That is why we normally show that the pulse enters like this and then comes out,

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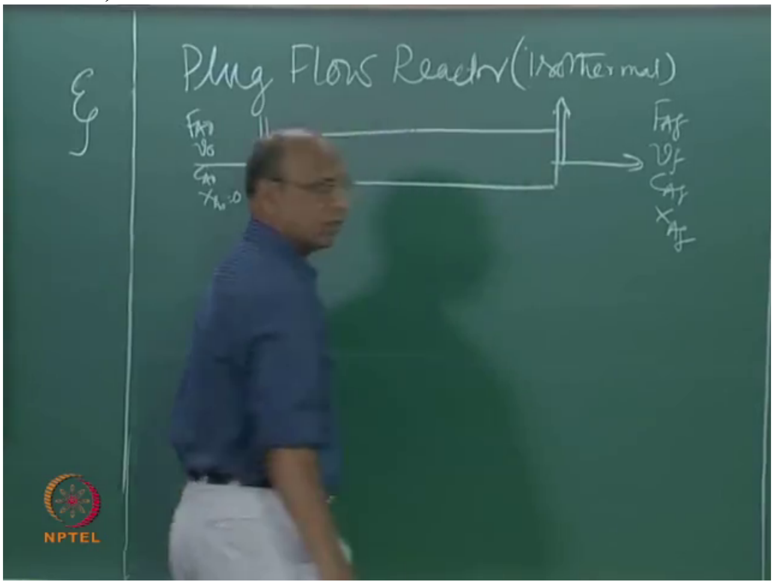

not reverse but same thing. This is what is direct delta function. This is what I asked another question, for ideal reactors, plug flow and zeroth test yeah, plug flow and mixed flow what is the E T?

This is the concentration we are talking but the concentration can be converted into more useful function called exit age distribution function, Ok. Why useful? I think we will discuss when we come to R T D. Why that is useful, why we should define like that? But this is simple concentration. Now pulse input, sorry, this pulse input we discussed.

Now let us say that I have step input. Step input is water is entering continuously, right. The color of water we know.

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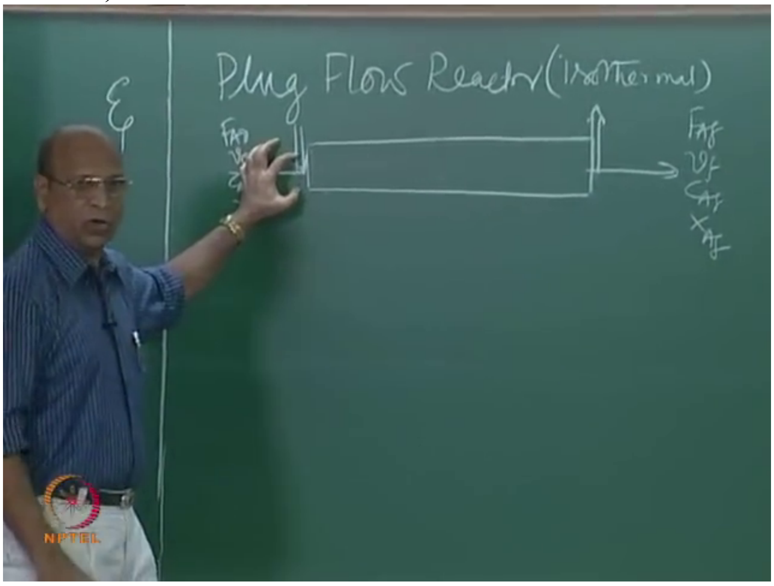

Then I will also have another stream of red fluid, red Ok, so then at time t equal to zero, I will switch off this, there is valve here, and there is another valve connected, the moment I switch off this valve, another valve will open exactly same flow, same flow, no disturbances, not allowed.

Disturbance is not, in reality we will have, no disturbance is allowed then I will allow this red fluid to enter and then come out. What do you see at the end?

(Professor – student conversation starts)
Student: After the residence time you will see only...
Professor: After time equal to 10 seconds you will see...
Student: Only red.
Professor: Only red, that is step input. You know the step entering here, something like this. And also coming out exactly, yeah something like that,

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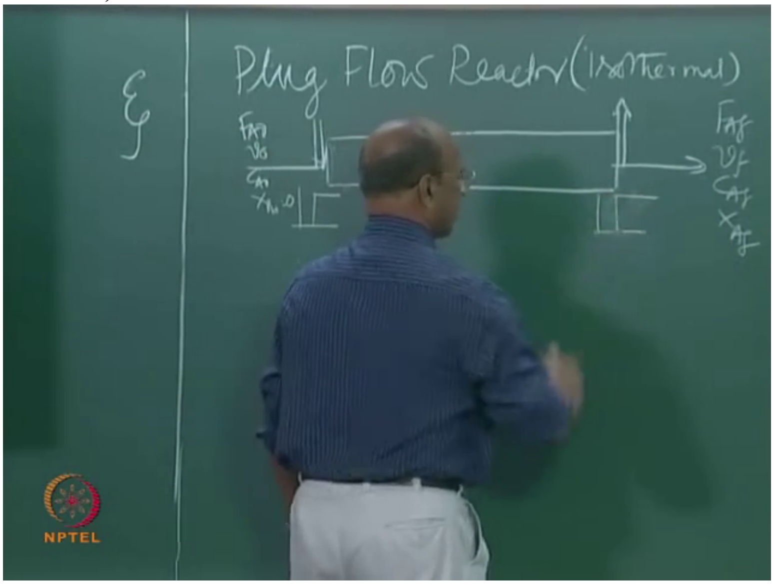

exactly like that.

(Professor – student conversation ends)

So R T D is also very easy now, for imagination once you have this. But in reality what happens? In reality when I have this, you know, we are talking about turbulence, turbulence in pipes. So that means turbulence in pipes is small fluctuations over the

(Professor – student conversation starts)

Student: Velocities

Professor: Velocities. So then what will happen to this disk when you have small fluctuations over, over these velocities?

Student: That will spread

Professor: Like how, how does that spread?

Student: Axis

Professor: Because you have uniform concentration in this disk, right? So it is..

Student: 0:26:18.0 concentration with the time.

Professor: Yes

Student: When it will come out,

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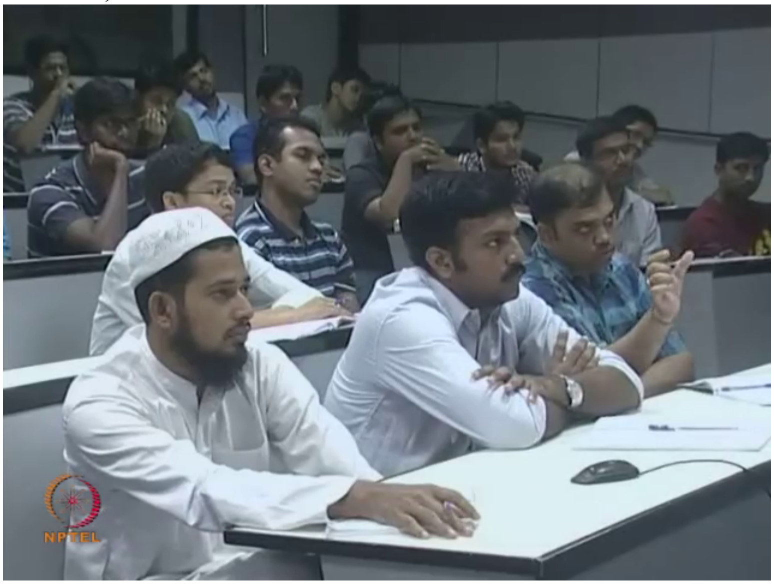

it will be more

Professor: Uniformly?

Student: In the center...

Professor: Yeah, center of what? Center of the..?

Student: Center of the pipe

Student: Center of the disk.

Professor: No pipe here, I think pipe it is just...

Student:0:26:35.0

Professor: Yeah, if I looked at the small, Ok let me draw this, you know,

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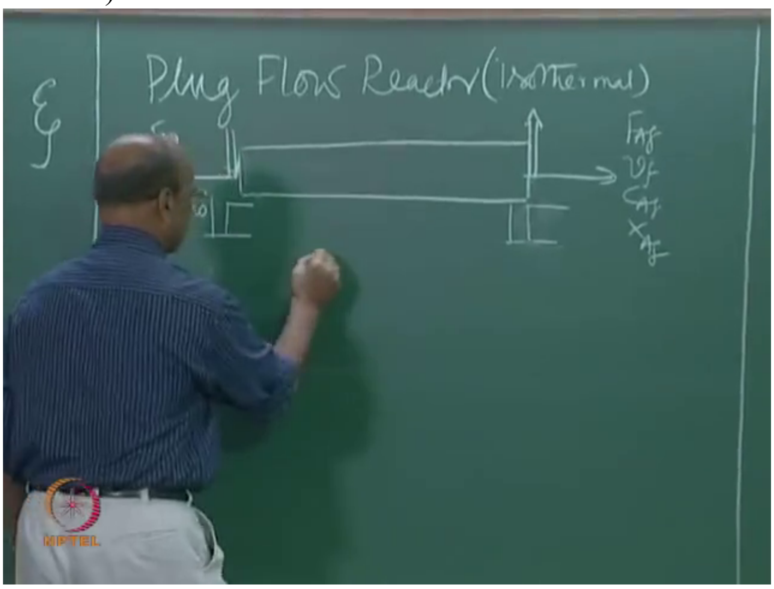

this is the disk I am introducing. It should be in fact infinitesimally

Student: Thin

Professor: Thin. But if I write infinitesimally thin you cannot see.

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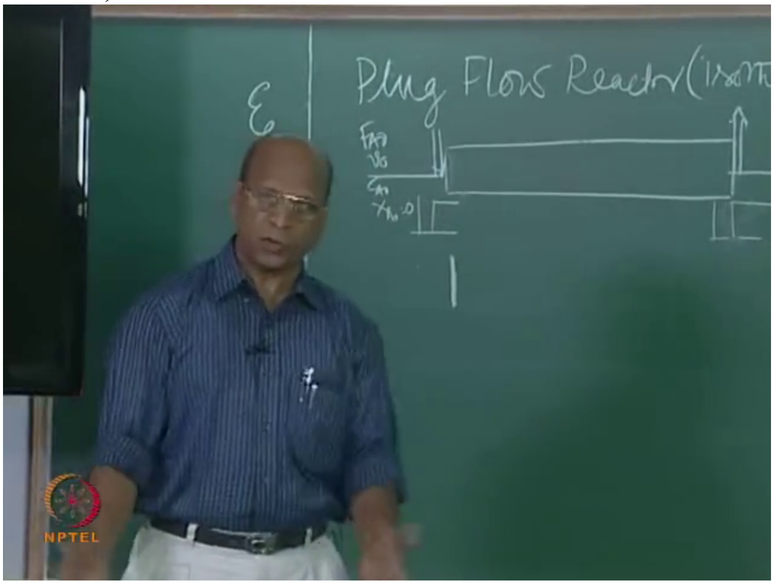

So that is why I am drawing it a little bit thickness. Ok. So imagination is this one, yeah.

(Professor – student conversation ends)

This is the disk I had just entered, right? And this is uniform concentration throughout.

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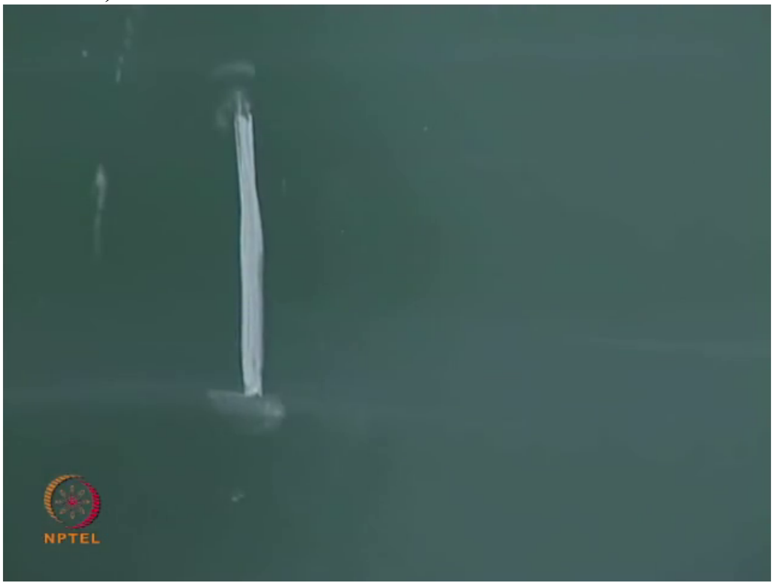

And when it is moving there is velocity fluctuations over this, around this, right. So how does that spread somewhere here? Somewhere here how does that spread?

See there what happens is the concentrations at this point, at this point,

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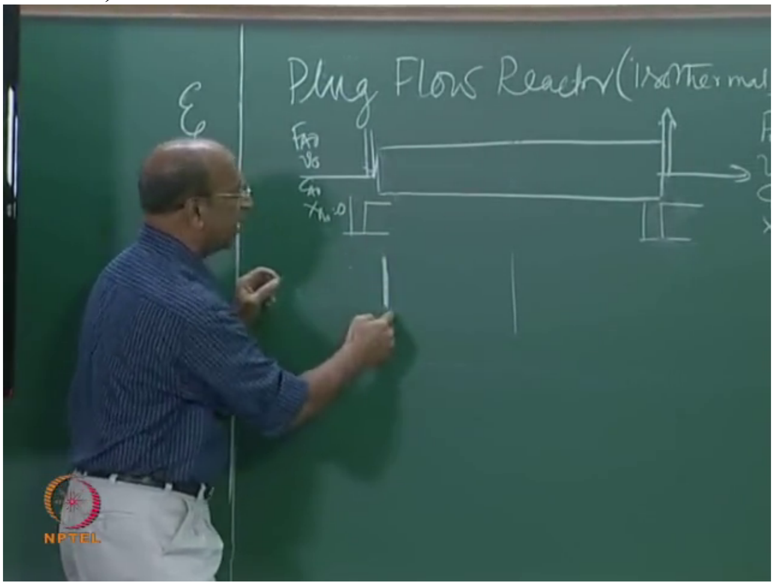

because this side water, this side water correct no, when I imagine somewhere inside, yes here, this side water, this side water we have.

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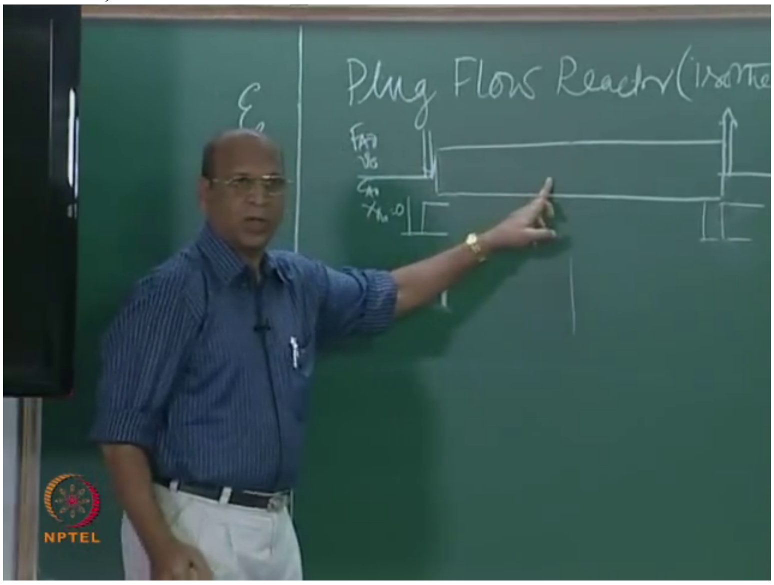

But now it is moving with the velocity fluctuations. So from here to here when it comes then the concentration here is less and the concentration here also less. So you will have like this. Concentration no, this is concentration I am plotting. This is the concentration. Ok this is the concentration and this is the distance.

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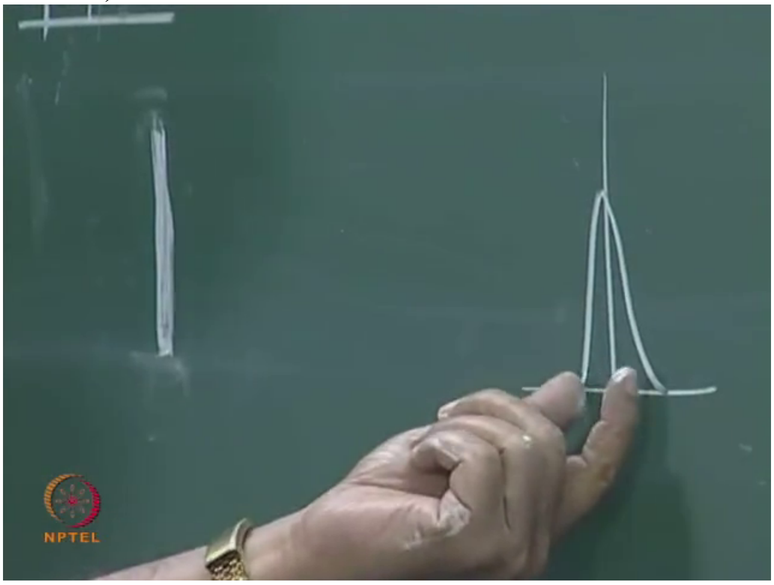

This is the thickness of the thing. Now that pulse is slightly getting widened. So at this point it may go like this.

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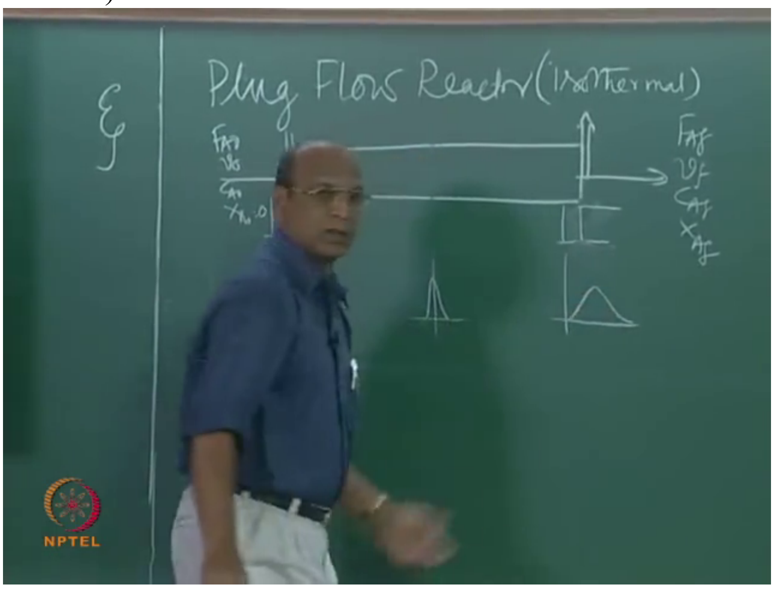

That is what is residence time. Now you see this is concentration only what we are talking. If I now, see this is time.

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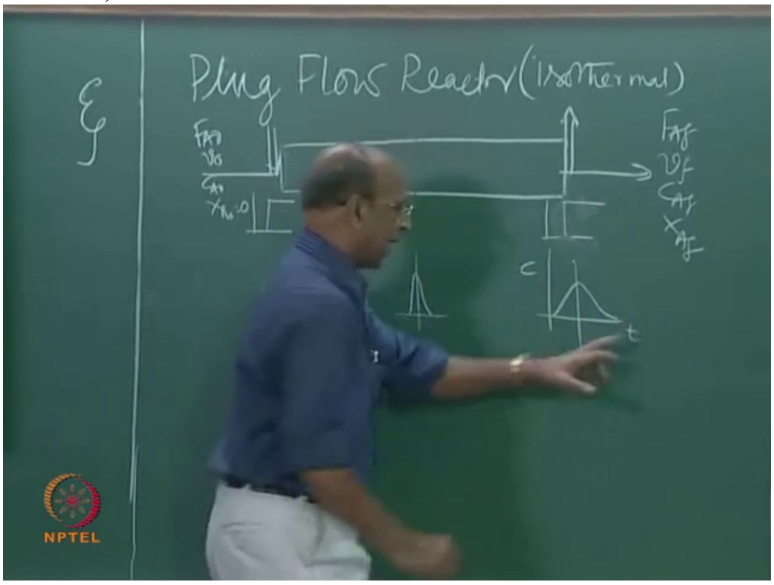

At this end if I see, so that means the, the molecules which are here, the front portion when it is moving, those things will come first and later at the center and later at the back.

So that is the disturbance what we have there. That is the spread in residence time. I also gave you some example that when you have this kind of fluctuations and if the average time is 10 seconds, some molecules may come in 8 seconds itself. Because of the fluctuations. I think, I do not know whether I gave this example.

When you are talking about that Tirupati queue, Ok, when you are about to see the God, may be of just entering that main temple, main, that portion, so then when someone pushes you, you are very happy because you will go and just jump before the God. Ok that means he is able to see at least may be a few seconds before than the person who is just in his line, Ok.

He was in that line but because of the forward backward movement, someone pushed him. So he felt forward. So that is falling, that is exit I am telling that is why. So then that means he will come slightly earlier. So that is why the molecules here, if I have 10 seconds

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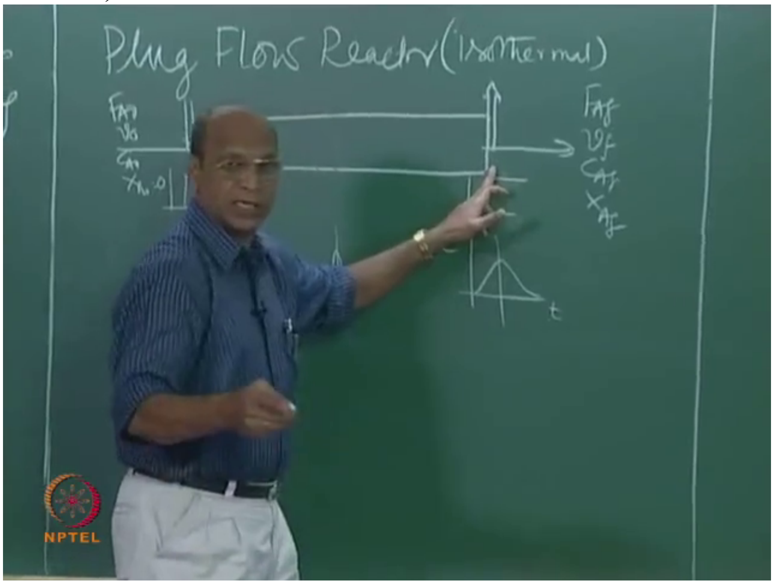

mean residence time, some will come in 8 seconds or 9 seconds and someone will come in 11 or 12 seconds.

But that is small disturbance. That is small disturbance. And in plug flow you will have only small disturbances. Because your velocity fluctuations are not large. If you have infinity velocity fluctuations..

(Professor – student conversation starts)
Student: Mixed flow reactor
Professor: Excellent, mixed flow reactor. Why?
(Professor – student conversation ends)

A molecule here is about to leave,

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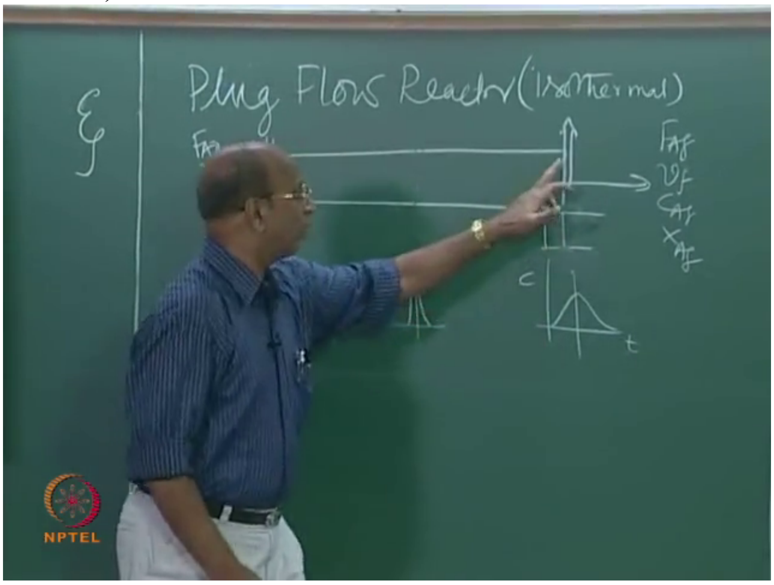

Ok then because of infinite fluctuations we have, there may be one fluctuation which will suddenly take this one here.

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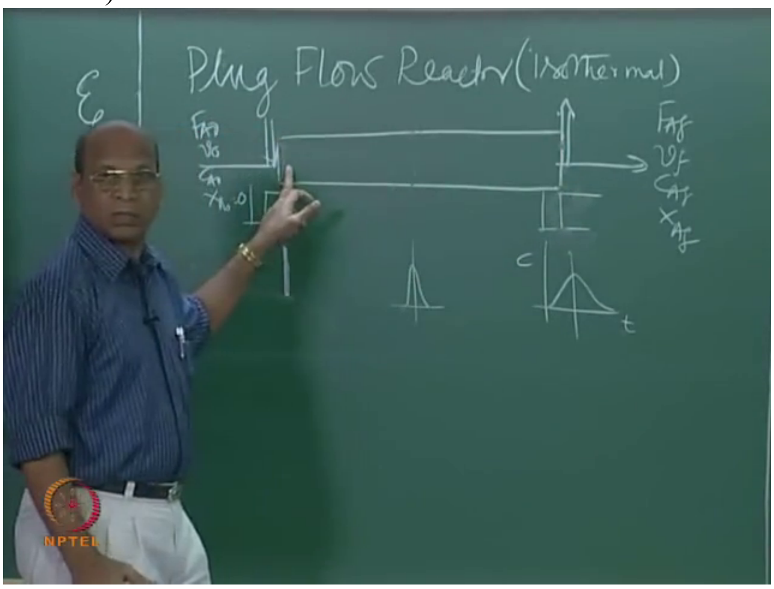

Ok, it cannot go out anyway because continuously it is pushed all the material, so then again suddenly it may be pushed somewhere here.

Ok so if you have infinite fluctuations that is mixing what you are telling then you will have throughout the reactor you have the same concentration, that is the other extreme. That is the other extreme Ok, that is all. How simple it is to remember these concepts you know but entire reaction engineering is based on this, again I am repeating that, that is why I am spending so much time. Because you should not forget now onwards at least.

That is all, very simple. And the resident time distribution wise also you will have very small distributions

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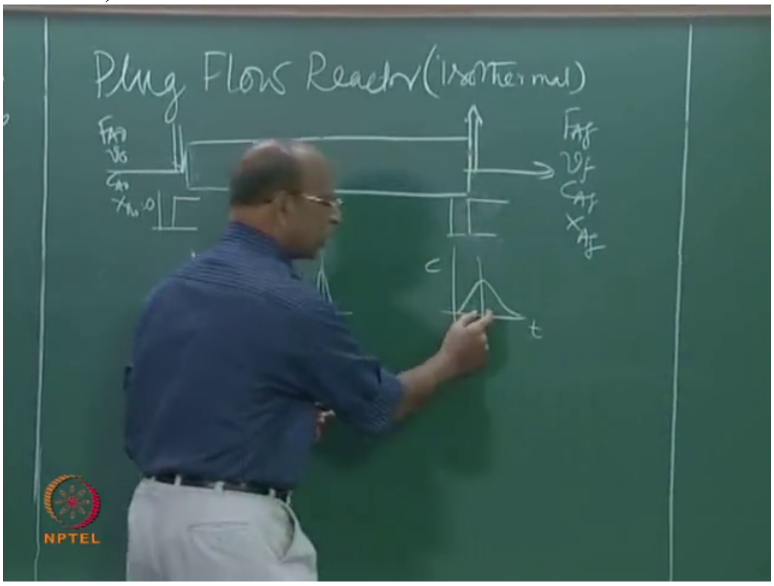

when you have plug flow. When mixed flow comes I will tell you how much distributions you will have there. Very small distributions only, normally. That is why, that distributions to take care of these small distributions we use what is called axial dispersion model, axial dispersion model.

Actually this is the correct model, for when you assume plug flow the correct model is axial dispersion model.

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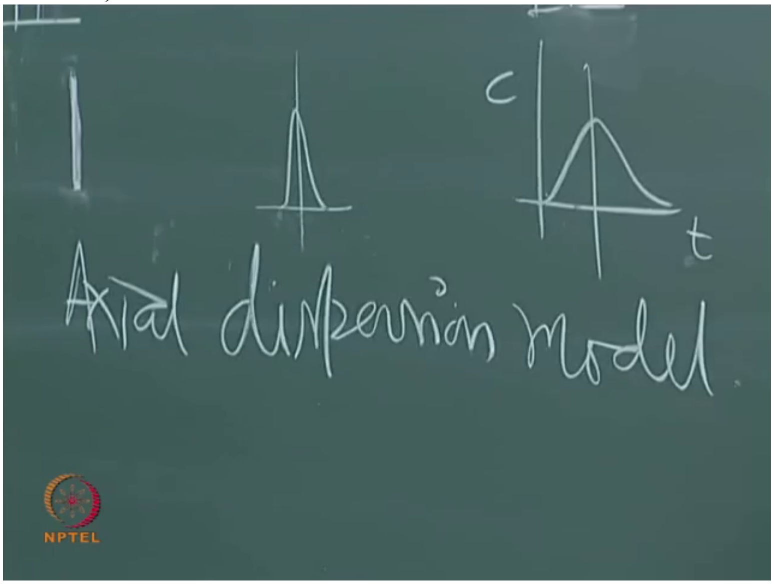

Because there will be some dispersion, you can never avoid that. Ok. You can only avoid if you are using infinity velocities. If you need, if you are putting infinite velocities then across the entire universe you have the length of the pipe. Correct no, velocity equal to infinity, so whatever length you put, zero, zero time only you can provide. I am exaggerating, Ok.

So, so that is why the correct model for any, any plug flow model is, the ideal plug flow model is, the correct one, realistic model is only axial dispersion model. But we take that and then we will first derive the equations, ideal plug flow to see what kind of equations we get and how far we can deviate from that?

We need processes by Shreve, everyday you are using his book. Shreve was the person who really pushed unit operations, unit processes name after looking at unit operations name. We also should have for reactors, you know all chemical processes are imagined as unit processes. That is why, the name of the book also, beautiful book, what is that book,

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that is the book, you know straightaway like

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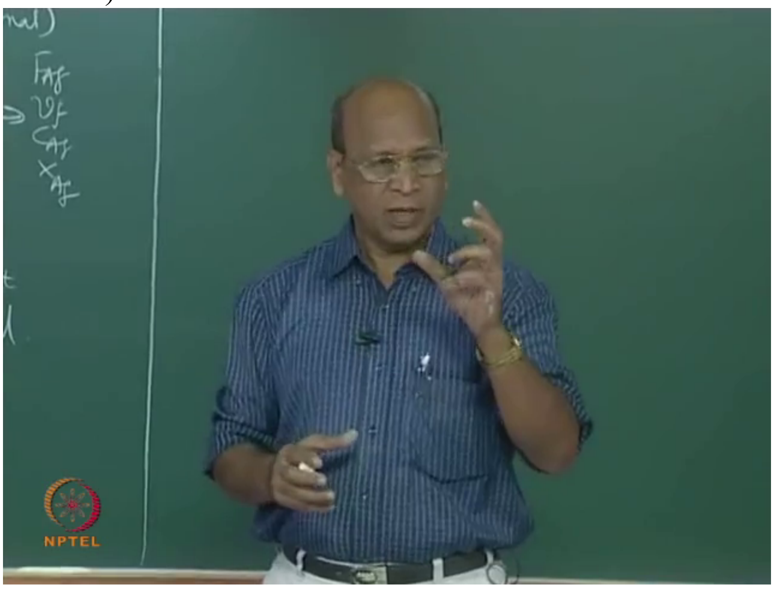

Levenspiel used Chemical Reaction Engineering after that, Groggins used Unit Processes in Organic Synthesis, all reactions you know, nitration, alkylation, tell some more?

(Professor – student conversation starts)

Student: Esterification

Professor: Esterification, it is not organic process, Ok alkylation all that yeah. All that they have, nitration, benzene, not benzene, alkylation there are so many things no?

(Professor – student conversation ends)

All those processes have been divided into unit processes. Ok and for chemical reaction engineering, who has put this name for plug flow and mixed flow, at least, just guess? Someone told Levenspiel but he is not Levenspiel. Levenspiel beautifully used all these concepts.

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Denbigh, K G, yeah,

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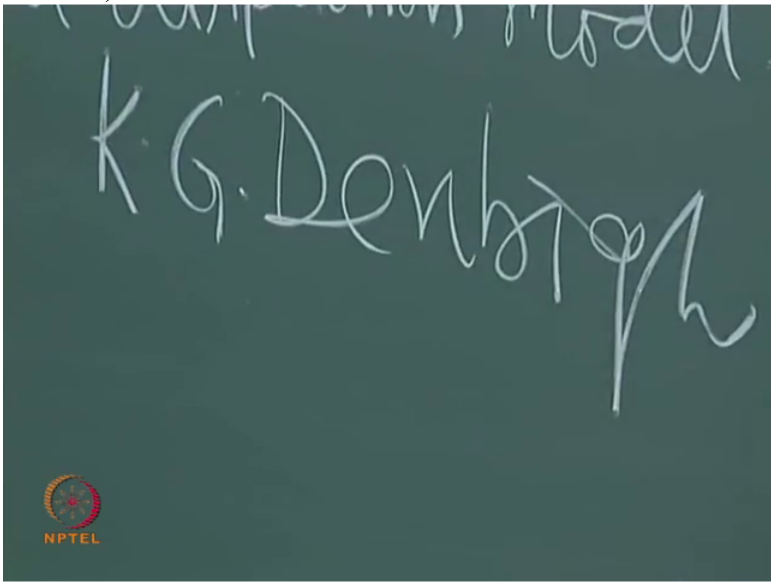

K G not grams, kgs. K G Denbigh, he is the person you know, the name is given to him that he is the person who has given, his writings are fantastic. He was from UK, I think he was in Cambridge, Cambridge University or so, yeah Cambridge only I think but wonderful writing. The way he writes, he won't use much mathematics, but he will tell all beautiful things about the subject in terms of words only. Conceptually he is excellent.

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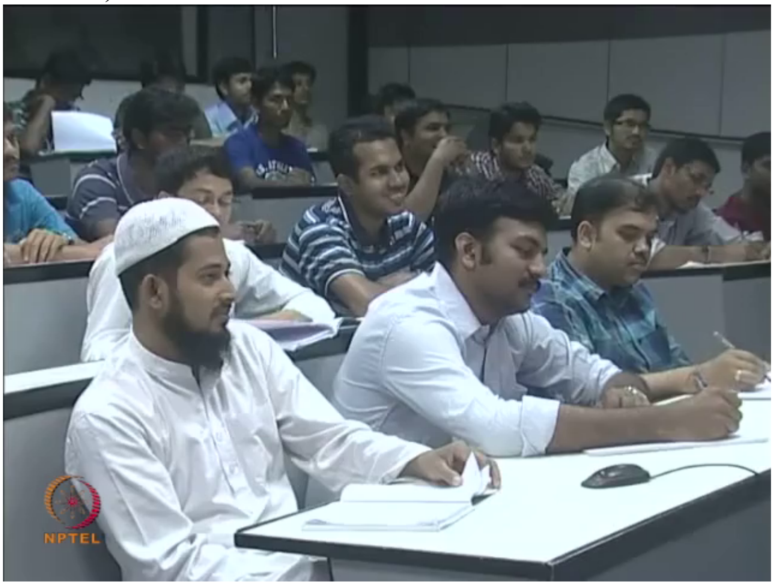

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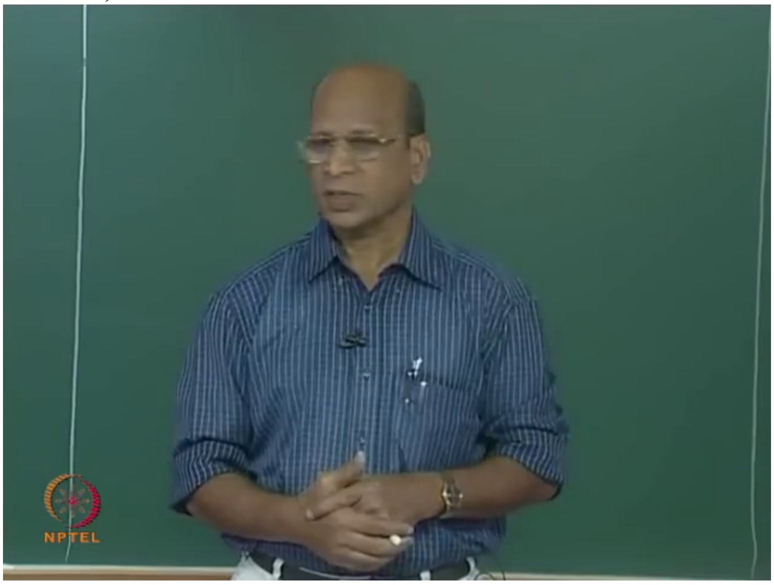

Chemical Equilibrium, the name of the book. This big book, maybe I think 500 pages, around that, yeah. Chemical Equilibrium, wonderful book! Again I think you know, you know thermodynamics is most of the time abstract and the nice concepts, nice words only we have to use.

So that is why this book is called one of the Bibles for thermodynamics for chemical engineers.

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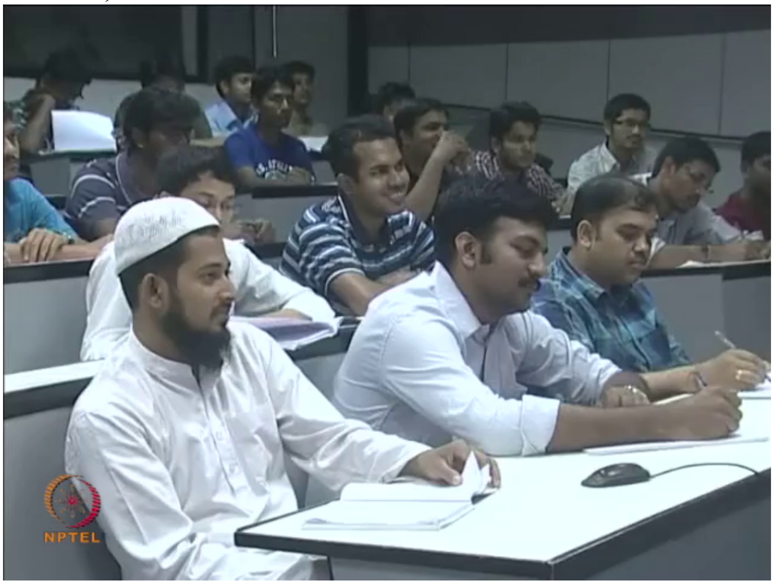

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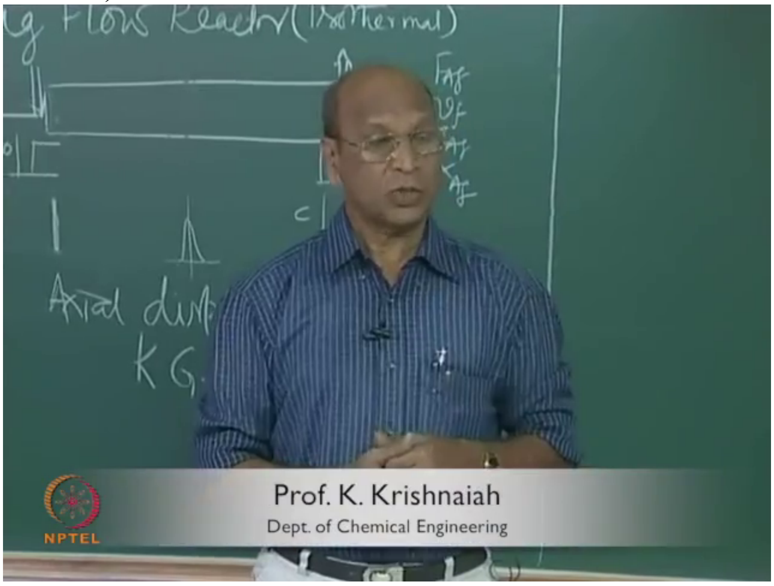

So that is why Denbigh books, wonderful book. Even if you do not understand, read it. 10 times if you understand you will automatically, 10 times if you read automatically you will understand. But you will not have time to read 10 times because all of us focusing only, Ok tomorrow exam, today night preparation. Over.

That is the problem with all of us, no. Our education system is like that, Ok. That is Chemical Equilibrium is one book. Another book is Chemical Reactor Theory, An Introduction, very simple introduction, that is the another name, another book, Chemical reactor Theory, in fact this course Chemical Reactor Theory was named after that book. It is coming for long time, almost 20-25 years, this course Chemical Reactor Theory, Ok.

Last 30 years I think this course is there in I I T Madras and that course is named only after that book came.

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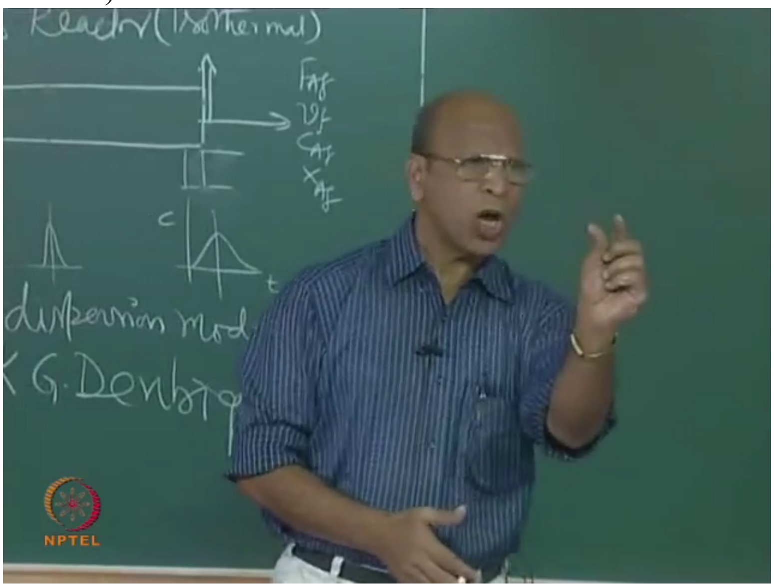

Small book, you can read like a novel. Not much mathematics but wonderful explanations. Even for plug flow also he will not mention directly time as the basic definition of plug flow but he will give two assumptions and then say that one assumption automatically requires this condition, the time of each and every particle is exactly same.

Like flat velocity profile, that is one assumption, one point he gives. So that one point, flat velocity profile should automatically will satisfy only when all particles are exactly spending same time, Ok.