Aircraft Stability and Control
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Lecture- 13
A Closer Look

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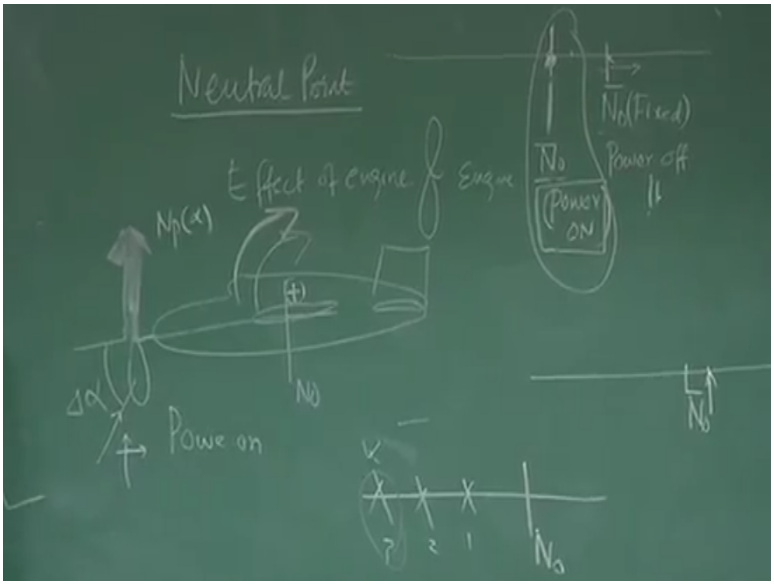

Little notes on Neutral Point okay what is neutral point? We have seen that neutral point is that XCG location, at which the aircraft become neutrally stable or DCM by DCL = 0 or DCM by D Alpha = 0, right. And so far we have been talking about neutral point where only wing, tail so and some fuselage contribution, although we have not computed anything. But we have never mentioned about the effect of engine, the effect of type of engine.

The aircraft is flying with. So we will take the effect of engine, we will take only 1 case propeller driven engine right, what will be the effect of the having engine in the nose and more precisely the question is, if this is the N 0 fixed that is stick fixed case with power off with power off then do you think N 0 will change with power on. So do you think the N 0 will change, with power on that means, when you switch on the engine for a typical airplane of this configuration. Suppose nose mountain like this, for this case I repeat the problem.

We are trying to understand the effect of Thrust or engine, on the neutral point this is the case power off, that is no power is there. No Engine is being rolled, and I am more focused to this sort

of nose mountain engine, without this being on, if this is N 0. Now the moment the power on case come. Power on so what will happen? Will the neutral point still remain at some point let us say here or it will try to go backward or forward that is the question, or in indirectly.

What is the question? With the engine on, whether the aircraft will become more stable or less stable, because we understand if N 0, let us say N 0 1 and this N 0 2 and another aircraft N 0 2, then I know that this aircraft is more stable than this aircraft because it has got a large static margin for a given CG location isn't it, for the given CG location this aircraft has this much of static margin, and this aircraft has larger starting margin okay.

So, I would like to know now what happens if thrust is on, will there be any modification on the N 0 stick fixed okay. Let see one thing we understand, if grinding of this propeller, adds most stabilizing effect to the airplane then our N 0 fixed should go backward so it will become more stable. If adding this nose mounted engine, if it contributes towards more destabilizing then this N 0 point shift this way clear, because it will become less stable.

So now what happen see, if this is the propeller moving and some Delta if it is seeing then you know that by momentum exchange, there will be a thrust generator small though in this direction, because some momentum exchange will be there one this direction another this direction.

So this force which is proportional to Alpha is now acting ahead of CG okay. So this will give any component or any force, which are ahead of CG that will give destabilizing effect right. So, this configuration will give a destabilizing effect. So the neutral point fixed will now with power on N 0 power on will come forward here instead of power off is here. Is it clear again I repeat, because of this engine thrust or engine power this propeller driven airplane.

If there is angle of attack, the movement of exchange in this direction also, that will give a force roughly I can write this, function of Alpha and since this force is ahead of CG, CG is somewhere here, for any positive Alpha it will give nose up movement and nose up movement means? It is destabilizing for a positive disturbance of Alpha.

So, this will contribute towards destabilizing effect, and hence the aircraft will become lesser stable compared to power off. So the neutral point will shift here. So this is the point where I write N 0 or N 0 bar or XN 0 or XN 0 bar, this is power on and power off is here clear. So when you are flying you have to ensure that, CG should not go beyond power on, then it will become unstable during power on right, is this clear?

That is the definition neutral point, if this is neutral point whether it is power on and power off, point is if the CG goes beyond the neutral point, the aircraft will become statically unstable. So, now you know when the engine power is on for this sort of a configuration then actually the neutral point is not what is I am writing here with power of case, it will give power on little ahead of it so, I must ensure that the CG of the aircraft should never go, beyond.N0 the power on so, this will limit the case how much backward I can take the CG okay.

So, the CG backward and the CG forward so, how much backward I can take that is dictated by primarily by N0 power on clear okay. Now next question comes, how further forward I can take the CG because, I know if N 0 is here, I put CG here I put CG here, I put CG here, I put CG here in all the cases it will be statically stable, only think if it is 1, 2 and 3, third case will be the most stable case, this is little less than the third case, it is less than the second case, but third case will be most stable case.

Now who decides, that can I put the CG anywhere in the front because I give a logic, if it is CG is forward of neutral point, it will be statically stable. So how does it matter to me? It will be stable let it be more stable. Do you know fundamentally, if an aircraft becomes highly stable, then I need to put large control deflection to trim it for different, different CL, how do I know that?

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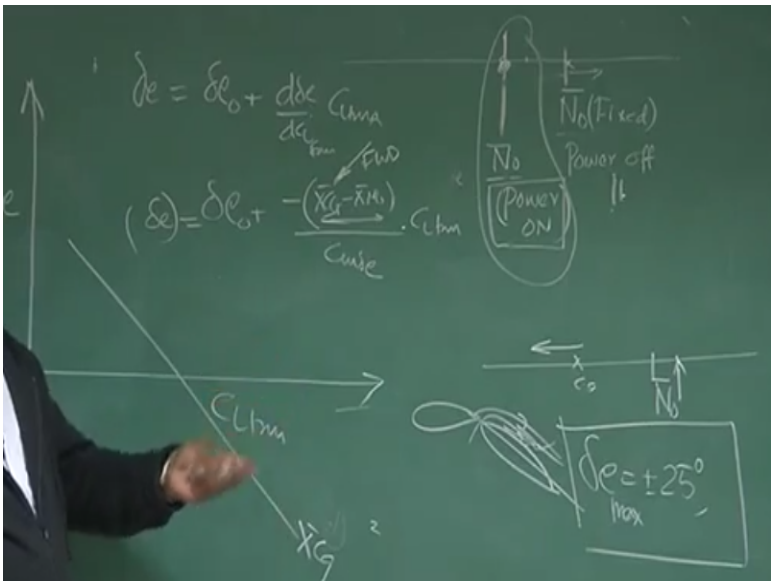

One is by simple common sense, if something is highly stable, it will always resist any change, which try to change its equilibrium to another equilibrium so, we need more effort right, but mathematically or expression wise whatever we have developed we could see here again, this expression comes to our rescue, you know that Delta E trim or Delta required is Delta E 0, + D Delta E by DCL into CL trim this is also CL Trim okay.

And what is this this is Delta E 0 + - XCG - XN 0 bar divided by CM Delta E into CL trim, this is = Delta E required. So, as I am taking CG forward suppose this is the airplane, and CG I am taking forward in this direction, so this gap XCG - XN 0 is going on increasing okay. Negative, negative, positive and negative, so what is happening as it goes on increasing the Delta E required also will go on increasing right and there will be limit beyond which you may not have realistic Delta E available because Delta E also have a maximum value of deflection, may be + - 25 degrees.

Beyond that the flow will stall over the deflection this is the elevator, let us say, so beyond fifteen degree of beyond 25 degree, depending upon what sort of elevator you are using, the flow may separate that is why every airplane is characterize with Delta E max is + -, let us say 25 degree, some high fidelity aircraft may have 30 degree, 45 degrees but almost of our normal airplane, it is 15 to 25 degree depending upon, what sort of technology you have used.

So the point is there is the Delta E max, you cannot exceed that, ok but if you go on making it this separation larger and larger, or the making the aircraft more or more stable.

This value may exceed the limit given by there. So, you have a restriction on how far you can put the CG forward because beyond point, this value is become so large that Delta E will may become more than the Delta E max required, typically the Delta E up required okay.

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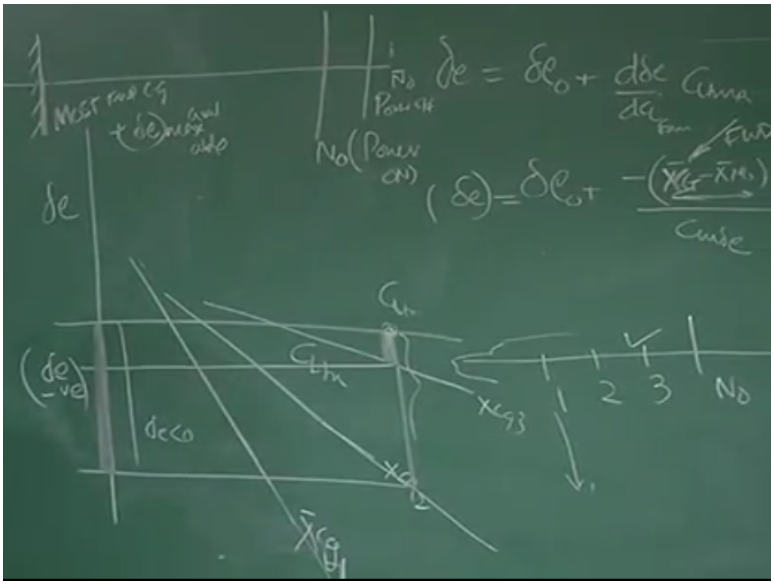

If I am moving the CG towards nose of the airplane that is, we are making it more and more stable as I moving CG forward pictorially if I draw Delta E vs.CL trim right this is one case highly stable another case, this is another case right here okay. What is the understanding here, in which case CG is most forward this is the CG, XCG is most forward because the slope is the highest here most negative, then this is XCG 2 I call it XCG 3.

Now, see suppose you want to trim at this CL trim value so for CG location let me draw it for your, this is XCG 3 this is 2 this is 1 right so this is the most forward right this is 1 here right. Most forward one that means neutral point may be somewhere here so, this is highly stable, most stable in this configuration.

So, now if you want to trim a aircraft for the particular CL trim, you see if am using this 3 location, where the starting point is least I need only this much of Delta E negative that is Delta E is up, okay but if change the CG to CG from CG 3 to CG 2, and the stability has changed, we

say now I require from here to here this much of Delta E required, which is again negative right this much it is much more compared to this value.

What will happen for this case, if I draw it like this value, will be exceptionally high. So what is the meaning, you mean somehow generated CL trim, okay but how much CL trim you can trim actually by elevator deflection is decided by what is the Delta E max available and hence, directly it also tells you what is the maximum forward CG you can put for so that your aircraft is trimmable, okay.

So, the aircraft is trimmable so, that I can trim the airplane further CL okay. That is very, very important so the most forward CG is primarily dictated by most forward CG + Delta E max available, they are decides what should be the most forward CG and most FCG is divided by N0 which is power on case, if power off somewhere here power off we have already seen, N0 power off.

So, now two different things are here one is FCG is governed N 0 power on stick fixed neutral point power on and forward CG is dictated by what is the Delta E max available for all practical purpose right. You may also wonder, what happen during landing when I am actually flying at a higher CL but the propeller is also rotating you may wonder, what is happening if I am trying for the landing where CL is also maximum.

But power is not on in a true sense is not a full power in theoretical sense I can say propeller wind milling right. Then what happens how do I take care of that so, as per as this course is concerned let me tell you should I proceed with how will you proceed so, far what you have seen this is the N0 stick fixed here I am talking about, stick fixed right and power off.

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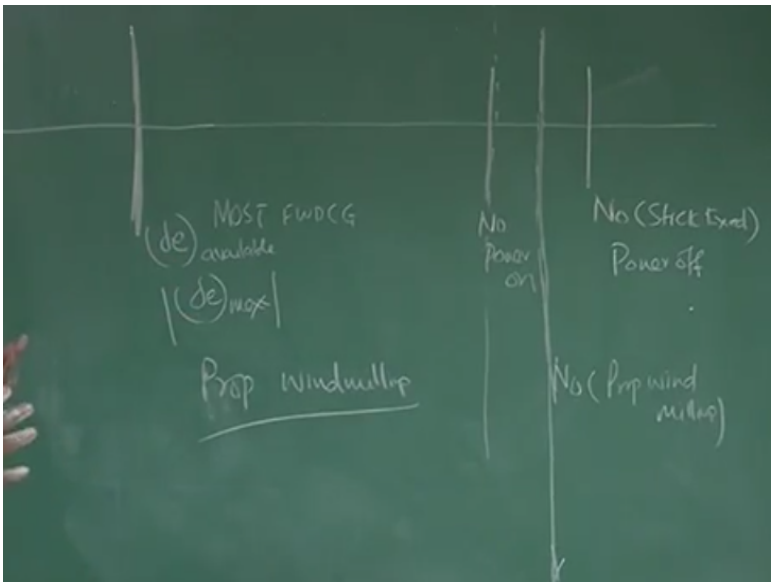

If the engine is nose mounted engine it will give destabilizing effect so N0 power on will come here, power on will be ahead of N0 power off. So, I should plan that CG of the airplane should never cross this it will become statically unstable during power or more. The next question came, how much forward CG I can allow the layout designer to put, then I realize that forward CG is dictated by the Delta E available.

So Delta E max that will decide how much really I can how much forward CG I can trim because after it will give more CM so I have to have any elevator power to control it, it will nullify it. This part we have a same, now second question which I was of course whispering is propeller wind milling, wind milling that is the special do landing it's not a full power it is propeller just wind milling.

So, that case if you see propeller wind milling it is neither power on but not power off right. So it is between these two so N0 fall wind milling should come somewhere here, propeller wind milling, should come somewhere here, the especially doing landing I should be careful about it, because that time N0 is somewhere here, N0 is not power on it will behind, but ahead of N0 stick fixed do you understand this or not?

N0 power on that time, it is contribute the full this stabilizing effect for a propeller engine in the nose of the air plane. But wind milling it is in between power on and power off for somewhere

here it will be there right. So for all practical purpose during landing this will be the limit of CG, beyond this CG it will become unstable.

But for forward, most forward CG this is the most forward CG when the airplane is at approaching like that it is at high CL max value and we need to know that I have enough Delta E max, which should be able to trim that CL okay. Because what will happen? As I move the CG forward and forward Delta E max requirement will go on an increasing we have seen that, and since there is a limit on Delta E max + - 25 degree.

So it will be more CG forward CG more governed by this, for this is a limit air putting, here and if you know these three things, three, four things you will be able to handle this at all situation, as we progress where when you for a little bit on as a stick (()) (17:52) free we will again come back to this neutral point and again address this things at this from designers prospective we will solve the problem and will try to get field for this.

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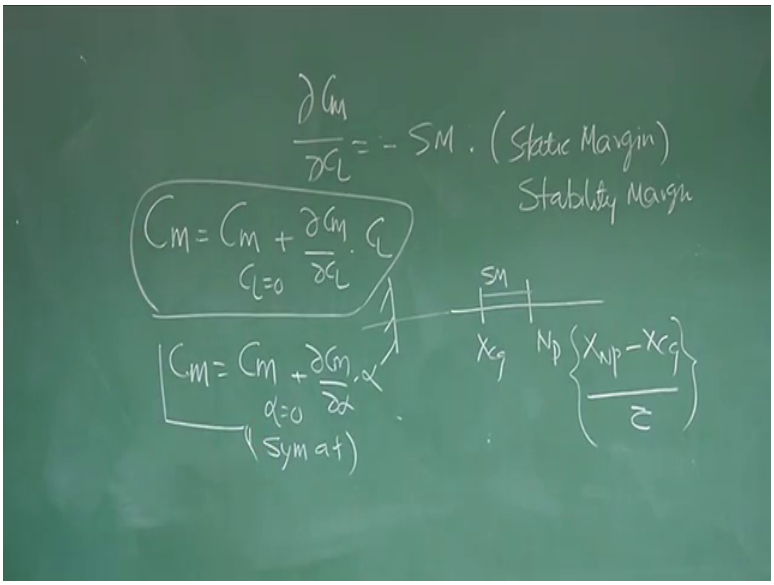

As I have been promising that once some theory, base background, is ready then we will be solving some numerical problem to get better in sight of those expressions, one of the derivations made was DCM by DCL = - static margin, right static margin, many books may also refer this as stability margin and we know meaning of stability margin is if this is the neutral point.

If this is the CG, I am measuring from some reference here, and this is static margin, of course this is expressed as a percentage of mean aerodynamic chord okay. We are not trying to say this how to utilize this DCM by DCL is = - static margin and get some insight about design. Once I am writing like this I understand the CM is expressed the CM at CL = 0 + DCM by DCL into CL, okay? This is the expansion.

For a symmetric aerofoil how do you write? We prefer if I want write in terms of Alpha I write CM at Alpha = 0 + DCM by D Alpha into Alpha. This is workable for symmetric aerofoil, but when it have been cambered aerofoil then I referred to the CM as CM at CL is = 0 + DCM by DCL into CL, okay. Now once we understand let us do a problem, problem is this let me write slope of CM versus CL is point 0 8.

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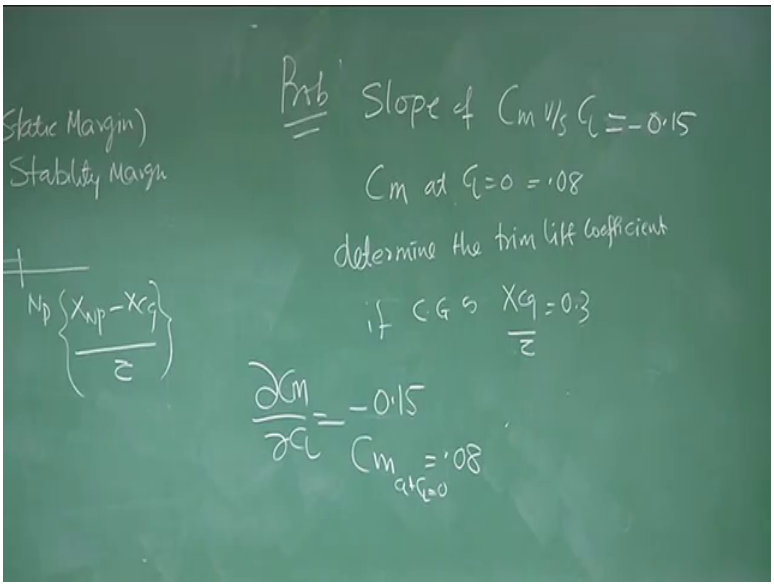

Then CM at CL = 0 is let me correct slope of CM versus CL is – 0.15, because initially I wrote point 0 8 is positive which is statically unstable right? So, minus sign okay yes its statically stable and what is telling is CM at CL = 0 is point 0 8 so you could see that CM0 is greater than 0 and DCM by DCL is less than 0 so statically stable and since the CM is positive it can be trimmed at a positive angle of attack okay.

The question is determine, the trim lift coefficient that is CL if CG is XCG by C bar is 0.3 let me again to repeat the problem for you to understand the slope of the CM versus CL is - point 1 5

that is DCM by DCL is - point 1 5, so I write DCM by DCL is – 0.15 so this is statically stable case and CM0 that is CM as CL is = 0 is point 0 8 so it is possible to trim at positive Alpha.

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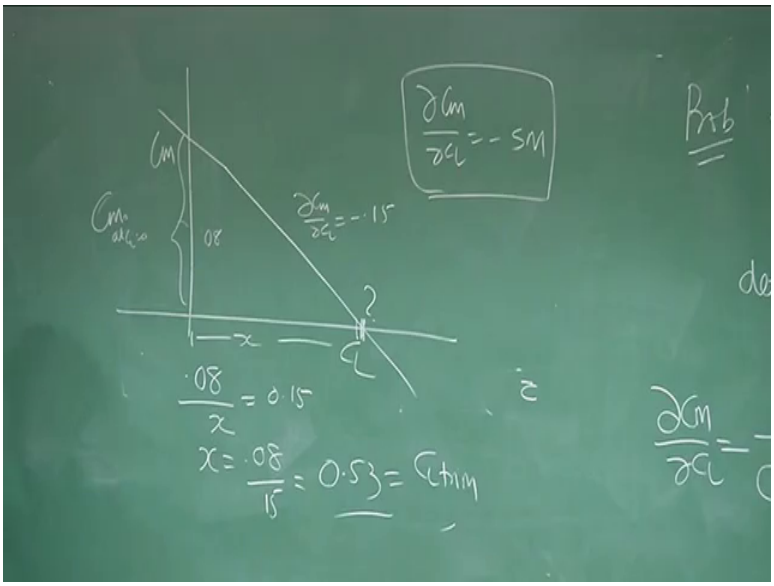

Question is determining the trim lift coefficient what is the CL for which it can be trimmed easily without doing anything else. so what I am trying to draw is CM CL the slope DCM by DCL is – point 15 and CM this value CM0 or CM at CL = 0 this value is point 0 8 what is this values CL trim the question, very simple problem. You know the slope of this line you know this so the CL trim I can easily find out like point 0 8 by.

let us say this is X by this X is point 15 the slope is negative we have taken out the negative sign so X I will get as point 0 8 by point 15 and which is approximately equal to you can check around point 5 2 or point 53. So this is the value of CL trim I will need not solve once I draw it like this know from triangle right angle triangle you can easily find out if this is point 0 8 the slope is - point 1 5 slope is nothing but perpendicular by base and negative sign you have to take and that negative value of so straight forward okay.

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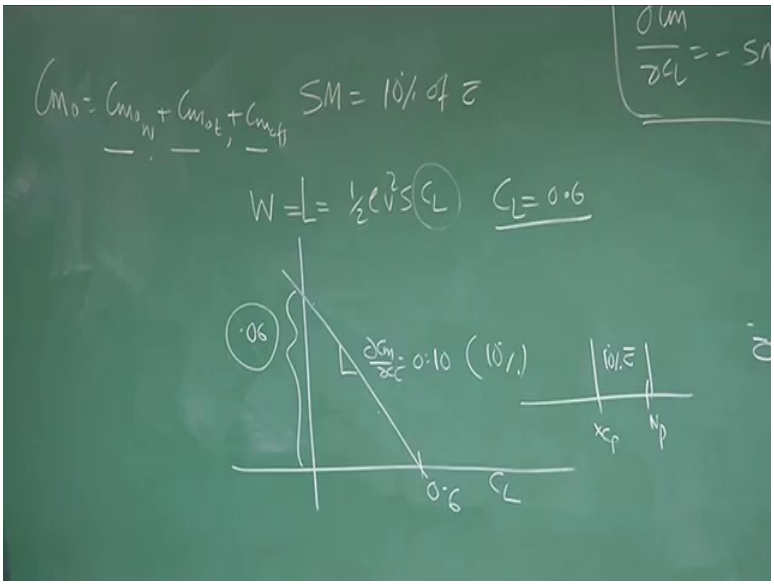

And see how efficient is this expression DCM by DCL = - static margin with this problem we will now go little further and try to extend its value when you are designing an aircraft typically if you designing a civil airplane you will design for a particular static margin may be 10% static margin that is 10% of the linear dynamic chord okay. 10 percent of that so now if want to select what is the wing area required or.

What is the CL I should design for you have a criteria like for CL typically I can write L = half row V square SCL okay? So and this = weight the lift = weight you know what at which would have to fly and you know what speed you want to fly you have your wing area. we typically get is some sort of the CL validate let us say CL point 6 let as point 6 you have get so what is the meaning of this 10% static margin right.

And CL point 6 I will write as point 6 and draw a line - point 1 get 10 percent so DCM by DCL is - point 1 because it is 10% and then to find out what is the intercept so this will be point 0 6 Now what I do I do I know CM0 = CM0 of wing + CM0 of tail + CM0 of fuselage, so I ensure the wing tail locations the area are such that the sum of this three quantity as of to give point 0 6 and the neutral point and CG they are located such a way that their static margin that is neutral point and CG this gap is 10% of new mean aerodynamic chord so how simplified.

It you approach becomes once you used that relationship you will know this when we do the design course may be we will be doing in one of the books but it's better that you should not only know how to find Delta E for a CL trim you should also know why we are doing this. So these examples are given to excite your mind that you start thinking in terms of utilizing this relationship for designing an aircraft, okay. Thank you very much.