Introduction to Flight

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Lecture 08.3

Steady Level Flight: A Pilot's View

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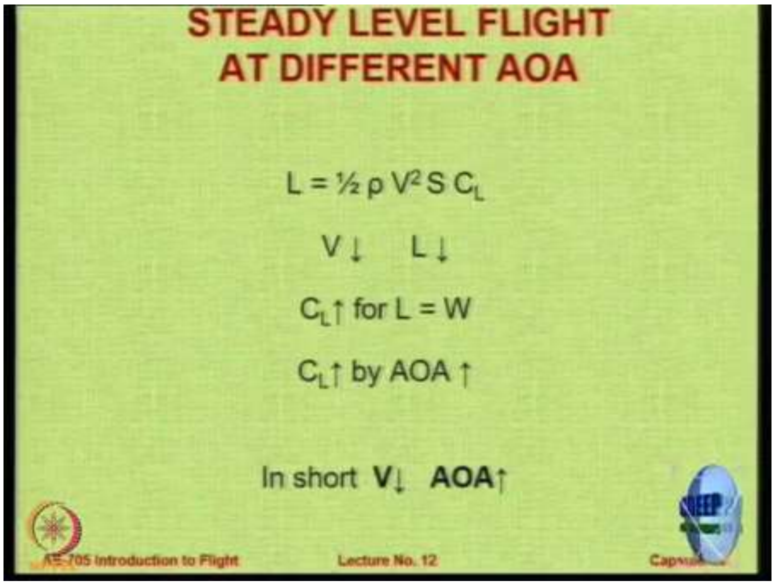

Alright, so now we already saw that changing the angle of attack of flight which the pilot does, can make you fly level at various velocities ok. So, the lift that you need should be equal to weight and that is the function of only $\frac{1}{2}\rho V^2 S C_L$ that is there in level flight. So, as the value of V reduces that means you want to maintain lift equal to the weight at low velocities, then if you cannot do anything else because if the altitude remains same then the density remains same, the aircraft is same so the 'S' remains same. So, the only option you have is, your lift will come down but if you do not want to lift to come down because you want to maintain the level of flight you have to go for a higher CL. In other words, you must change the angle, okay.

So, the angle of attack at which you fly is the function of the velocity at which you are flying for level flight. So the aircraft is going to fly at a lower angle of attack at higher speeds. Sorry yeah, and at a higher angle of attack for lower speeds.

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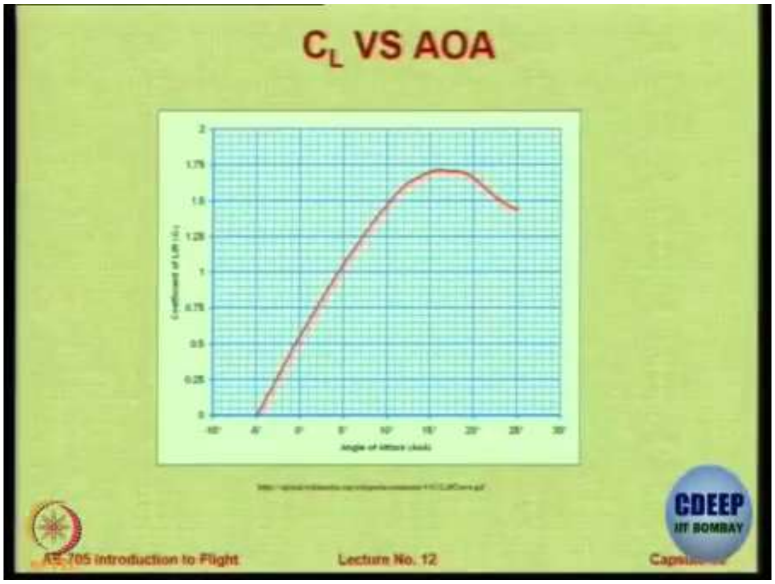

But you know that there is a limitation, you cannot keep on increasing the angle of attack because you will hit the stalling value, so that is how limits are imposed. You cannot fly lower than a particular speed because you will stall. So, whether you have the power available more than power required does not matter, you cannot fly because here you will not be having lift equal to the weight. Remember for Level steady flight, both the conditions have to be met, you have to have lift also equal to weight and thrust also equal to drag. So, you may have enough thrust with you at low speeds to overcome the drag, but you may not have the capacity to maintain the level flight, ok.

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So, now let us go inside the cockpit and let us have a look at how pilots are going to do this. The pilots do not have any angle of attack meter, they do not have any way of knowing which angle we should we fly they fly with reference, so let us see how they do it now.

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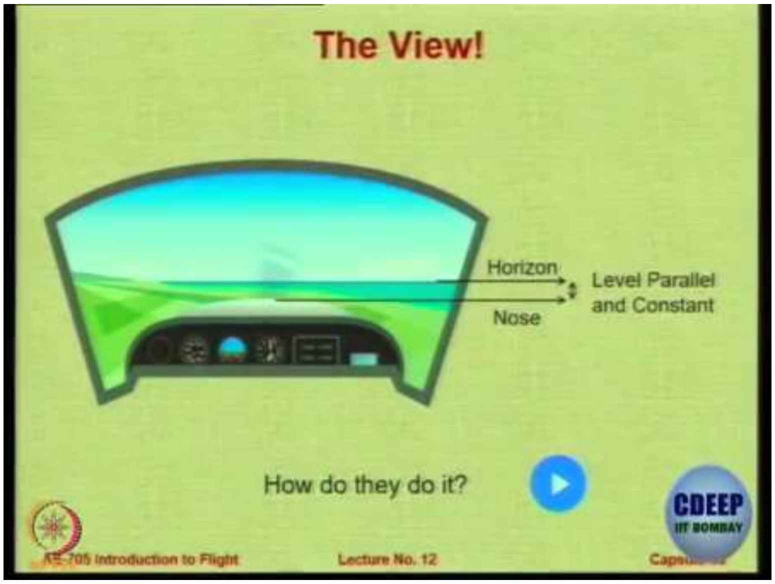

So essentially for the pilot you have a cockpit which gives you a view outside and in the outside zone there is something called as the horizon. This horizon should be maintained horizontal because if the horizon is changing it means you are not flying level you are flying at an angle, you are rolling and then, there is the nose in the aircraft. Now, I am talking about the small aircraft, something like the aircraft used by, general aviation aircraft, small aircraft, they will have some kind of a reference point on the aircraft say the nose or there is one more reference point called as the Spinner. What is meant by a spinner, do you know? See, in front of the propeller, you always have small conical projection, that is called as a spinner so that also becomes something like, it houses the propeller assembly and you give a nice aerodynamic shape to it because its first thing that faces the floor.

So the spinner is the fixed item, it spins with the propeller, so it remains relatively at a fixed location so that can also be my reference point. For the pilot steady level flight will occur, when you maintain a constant gap between a reference point on aircraft say the spinner or the nose and a reference point in the field of view or in the horizon. Let us say, there is a building or a church which is quite far away so if you maintain that gap, you are flying level. So let us see, a short video taken from a pilot training manual on how they do it. It’s a very interesting video.

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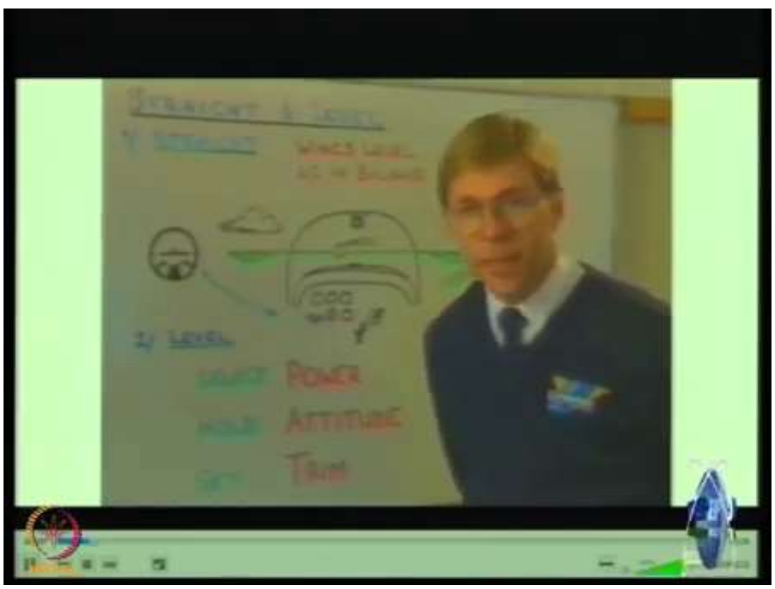

Video: Straight and Level flights- In order to fly the aircrafts straight, we first of all select the reference point towards which it will fly. We keep the wings level with the horizon using aileron. We keep the aircraft in balance using the rudder. If the ball went to the right, rudder will be required moving to left, left rudder will be required to bring the ball back to the center. To fly the aircraft level, we need first of all to select the level flight power.

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Professor: Remember. When you are saying level flights, you also do not want to have a flight like this, it should be straight and level, straight, steady, level. Technically speaking, a flight which is like this also straight and level but that is not what we are looking at. So therefore, the cockpit has an instrument called as a turn and bank indicator where there is small black colored ball, which is floating in a fluid and if the aircraft goes banking then the ball goes outside a small socket. So, the pilot brings the ball the back into the socket by controlling the ailerons. Similarly, similarly there is a problem with the yaw, actually they use a rudder not aileron ok? Similarly, there is, you will see that very soon they will show you a video in flight.

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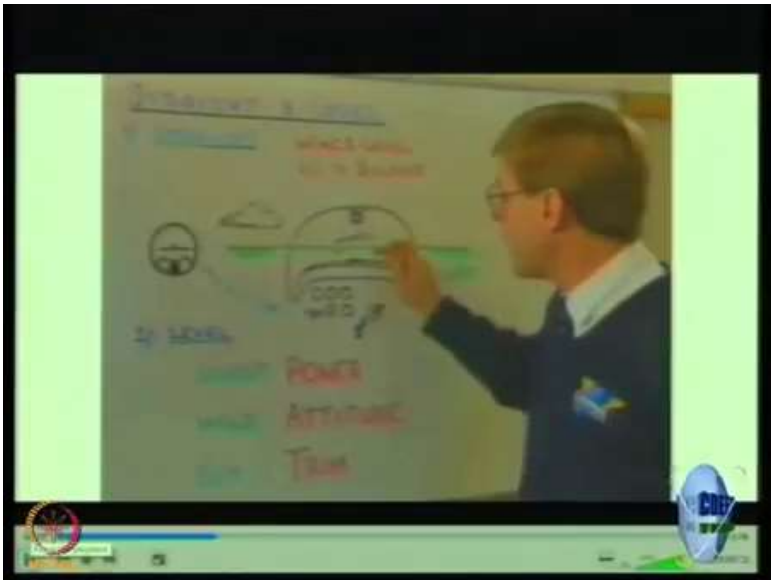

Video: Compiled with the correct level flight attitude and that is the distance between spinner and horizon. Now, as long as the power is set correctly and the attitude is set correctly and the aircraft is in trim, the aircraft will maintain level flight, which can be confirmed by the reference with the altimeter.

Professor: So, there are three things; you have to maintain, the correct power, the correct attitude so that gap between the fixed object here and in this horizon remains constant and also you have to trim the aircraft correctly. But now my question is many people do not understand the meaning of trimming the aircraft. What do you mean by trimming the aircraft or When can we assume that the aircraft to be in a trimmed condition? Can someone define when is the aircraft trimmed?

Student: When the center of gravity is slightly shifted then we just vary the horizontal at the tail, horizontal stabilizer by some angle and that is known as trimmed to make aircraft.

Professor: See! What you are saying is about what an Engineer does to the aircraft so that it can be trimmed. I do not deny what you say. And that is the only one thing, that is the only, that is only the horizontal trim, ok or trimming in pitch. You do it by adjusting the tail. My question is, what is trim? When do we do say that the aircraft is in a trimmed condition? Yeah! Maybe can you answer?

Student: Sir, when all the controls surfaces neutral positions is maintained, neutral position is maintained.

Professor: Correct! so that means ok now let me go one step further. When is the neutral position in an aircraft maintained?

Student: Sir, before flight it is not referred to zero based on the flight requirements, control surface is set at some adjustments may be up or down, so that the initial position has to be maintained.

Professor: No! Again, the same thing. See, you are talking from the Engineer's point of view. What do you do to trim the aircraft is you adjust the control surfaces at some positions, ok. But my question is, not what you do but when does the pilot feel that the aircraft is trimmed?

Student: When he removes the stick, there should not be any, when he leaves the stick in stick free condition, control surfaces will be in same position.

Professor: Yeah! That is important in a stick free condition there should be no net moment, that is what I am looking for. In a stick free condition there should be no net moment. If the pilot has to apply some control forces, to ensure that there is no moment, it is not trimmed, it is untrimmed condition you are forcibly adjusting it. But, so you have the trim wheel in aircraft, you have trim tabs behind all that is there. But when everything is done, you fly hands free, the aircraft flies without any net yawing moment, net pitching moment, net rolling moment unless there are weather disturbances then of course they will come, okay? But if it is a stable aircraft, which we will see after a few lectures, it will almost comeback. So, from the pilot's point of view, trimming means removing all imbalances which may be there. Great! So now, let us see inside the cockpit now.

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Video: Ok`! Now we get to look at straight leveled flight. Let us divide this into two (parts). First of all, level flight, to find the aircraft level, two requirements: first the level flight have (to be) correctly set. Second the level flight attitude. You can see where the horizon is cutting through the Wind stream, that is the position, in this aircraft, the level flight. You know it is like funny to learn, if its like the attitude, you can see the horizon colliding with the Wind stream. To know it is pointing towards the ground, the way it began to lose the height. If I have steady too higher attitude, the compass happens nose pointed towards the ground.

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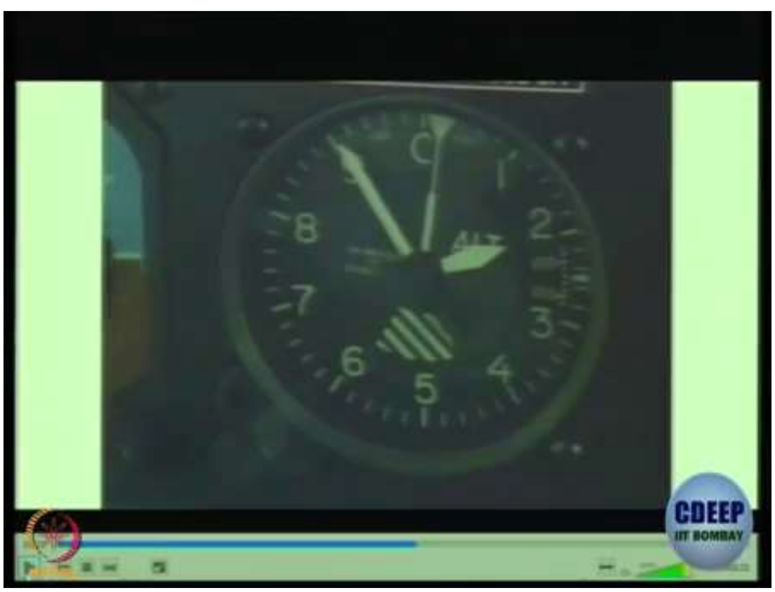

Professor: This instrument is a vertical speed indicator, which we saw in the instrument and it is not stationary, it is showing some vertical speed, which means, the aircraft is going in this case, it is going down ok, so that should not happen in level flight.

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Video: lose the height. If I have steady too higher attitude, the compass happens the aircraft begins to glide. So, these are these attitudes that you know to learn about those attitudes is correct because we know that is this power setting match is correct level flight attitude.

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Alright let us now talk about straight flight to fly aircraft straight again two requirements the first one keep the windows level its various having windows like that will turn. So, you got a keep the wings level to the horizon and the second requirement is to keep the aircraft in balance. The black ball means.

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Professor: There you see now if you just focus your attention on this instrument here, ok? This instrument shows aircraft as a reference and these two dashes are the horizontal line and there is this ball which is visible here and slowly moving out. Why it is moving out? Because the aircraft it is not leveled it is slightly banked towards the right side. So, for the pilot it will be difficult to orient in cockpit which is horizontal, so the pilot looks at this particular instrument specifically looks at the two ticks at end of an instrument and reference line of the aircraft. They should be in the same line or visually appealing will be, there a small ball here; it should be centered so the pilot will simply do the controls so that the ball is centered. You will see that now.

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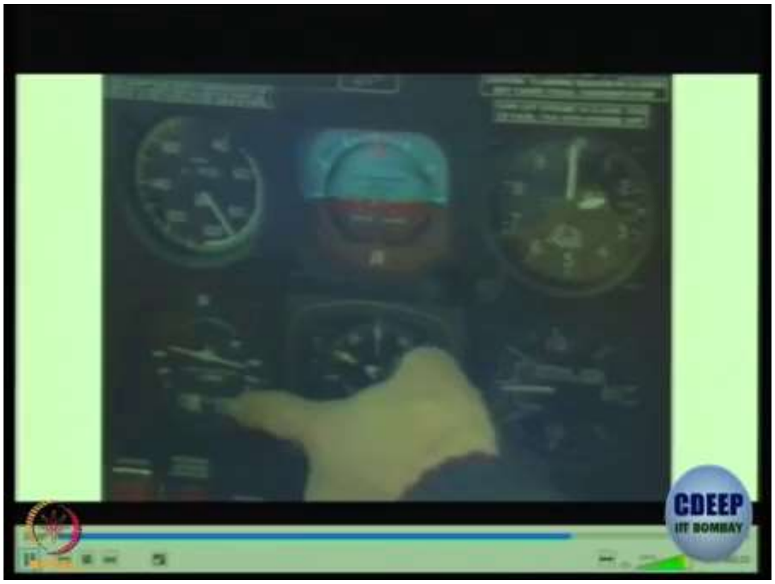

Video: We kept central. Now, before we fly the flight straight, select the reference point. If you look ahead, I have slowed the nose. You could see, I got a beautiful chimney in view. And as long as that chimney remains in my 12 o'clock position, I know that I am flying straight. Further confirms, of course by looking at directional gyro indicator, to confirm that we are maintaining heavily required. So, in a nutshell that is flying straight and leveled.

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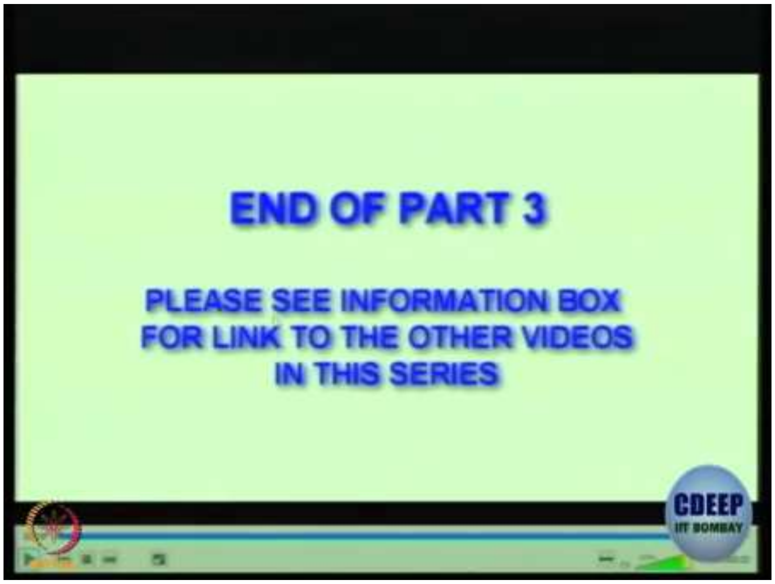

Professor: Ok, so for the pilot flying straight and leveled is little bit different from for an engineer.

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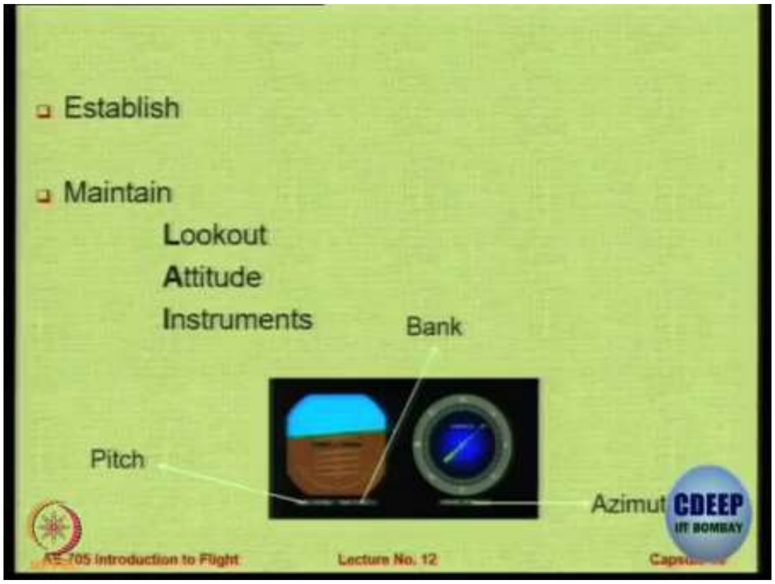

Alright! So, what are the objectives of level flight? You have to establish a few things and then you have to maintain. First is, you establish the correct amount of power so that your power required is equal to your power available. You are at the right altitude and you maintain that, ok? And then you trim or balance the aircraft. So, after you establish, then you have to maintain it because as a function of time, you cannot have sinking or raising. So for that, you have to do three things; one is look outside. Check the reference on the aircraft and the horizon and maintain a constant gap between them and look at the instruments in the cockpit, which are going to help you. So now, suppose you fly in night time and you want to fly. Now, can you imagine what would be the requirements for say a military pilot?

Student: Sir in every case the horizon may not be straight; it might be uneven right, so in that case, how the pilot could?

Professor: That is a good question, I wish you would have asked me this question. So, now let us see what other people think. His point is very much valid. Number one the horizon may not be visible, night time no horizon. Secondly the horizon may not be, so see it depends on how you define the horizon. So, horizon is defined as that line which is remaining almost flat and constant in the view. So, either you have a horizon or you do not have it.

Student: But the pilot cannot know sir, whether it is remaining constant or not.

Professor: If the pilot can see something that is horizontal and remaining horizontal, that is the is horizon. If the pilot cannot, and the pilot flies by the instrument that is exactly what I was saying. Night time flight, flight over an ocean where the horizon is very far away or may not be available to you, flight in against the black background, there is no horizon now. In those conditions, the pilot flies by instruments because, the instruments in the cockpit are independent of the horizon. There is a turn and bank indicator, there is a climb, VSI (Vertical Speed Indicator). So, you look at the vertical speed indicator there should no vertical speed visible, the ball should be in the center, that means you are flying horizontal and level, look at the altimeter that should not be changing, that is all, that is the only thing available.

But can you think of a situation, what could be the requirement for a military pilot to maintain steady horizontal flight? In which scenario do you expect this to happen for a military pilot? Pitch darkness, no horizon, can you think of a scenario? In other words, why it is important for us to study and to know about steady horizontal flight? So most of the armament that you launch, especially when you are launching precision bombs, which have to be guided it is desirable that there is no great change in the acceleration of the aircraft otherwise, there have to be more corrections have to be made in the aiming system. So, steady level flight is a very useful requirement even for military pilots not only for transport pilots, ok.

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Just to move on and to increase the scope slightly let us look at now, helicopters. They also maintain steady level flight, yes or no? We see them flying across our campus regularly, generally they are in steady level flight, ok. So that means they must be doing something also? So, let us see what they do so let us see.

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This is the other helicopter so, this particular video is just a kind of an introductory video about helicopter and aircraft. How are they similar in level flight, the difference is that is a rotary wing and that is a fixed wing, that is the only difference.

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So, there is something called collective pitch lever in the cockpit.

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The collective pitch lever is something that changes the angle of blades, all blades together, collectively together. So, see how it is done so as the collective lever is adjusted up or down, the whole assembly will move up or down. So, when the whole assembly moves then angle of each blade is being change by the same amount. So that raises collectively the angle of rotor blades, gives them more lift, so the helicopter goes up. Now, you can also bring the helicopter down, by pushing down on the collective.

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So, when you push the collective down, the whole assembly goes down. So, when the whole assembly goes down then the helicopter is going to go vertically downward. But remember that, in a helicopter it is very important that the angle of the blades is continuously changed as it goes across, otherwise what will happen is when the blade is advancing, there is some air coming from front, ok? So, advancing blade is going to get more relative velocity compare to the retreading blade. So, therefore across the rotation of the blade of the helicopter the angle has to changed continuously so in the retreading position or in the rearward motion the angle is going to be come down or in the forward motion the angle is going to go up and this is going to happen in entire cycle. So, this particular change in the angle which is cyclic is, obtain by the slots plates mechanism you can read about it yourself.

And the collective is collective or total one, but now suppose I want to move the helicopter forward, then I cannot have the same angle in all the blades collectively because that will give me only vertical motion. Now, what I want to do is, I want to tilt the vector forward so for that I have to give a cyclic pitch so there is a cyclic pitch lever with that angle of attack is changed cyclically so that the net force is forward and helicopter can move forward that is how the helicopter functions, ok.

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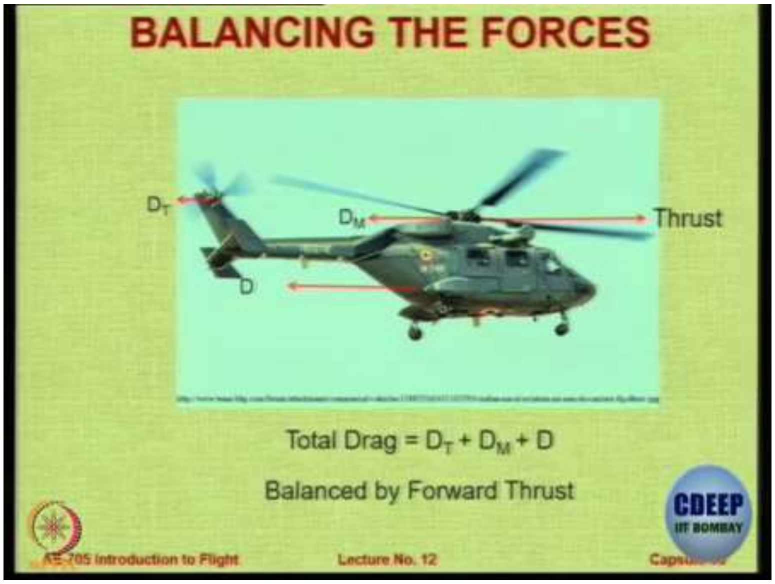

Now, look at the balancing force of helicopter, it is similar to that in the aircraft. You have a drag force acting on the main rotor that is DM because it is a rotating blade, you have a drag force acting on the body which is D and you have drag force acting on tail rotor which is T. So, the thrust that you produce by tilting the rotor blades forward should be equal to DT plus DM plus D and the lift that you produce again the rotor blade produce lift, they have to be such that lift equal to the weight. And now, you may also again have moments because they may not be the balanced at the same point. So, then same trimming mechanisms have to brought into place.

In some cases, the flat tail on the back that you see here, this tail actually helps in creating this balance, that is why we have small horizontal tail fixed on helicopter so that the moment can be continuously balanced but further trimming can be obtained by adjusting.

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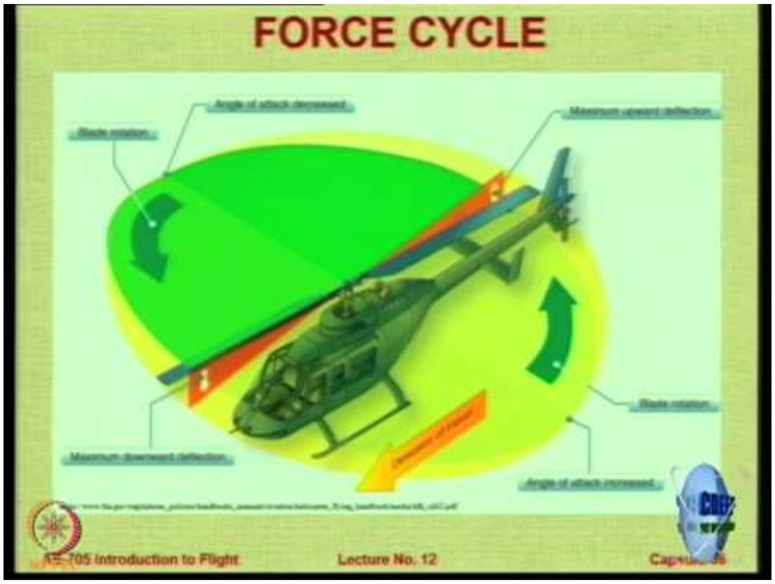

Yeah, this particular diagram I have already explained to you few minutes ago. This shows the working of the helicopter, so this you can brought at ledger. Ok.

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The last thing we will do today is to look at what happens to the thrust and power required and available as you change the altitude of the aircraft, so the conditions do not remain same at all altitudes.

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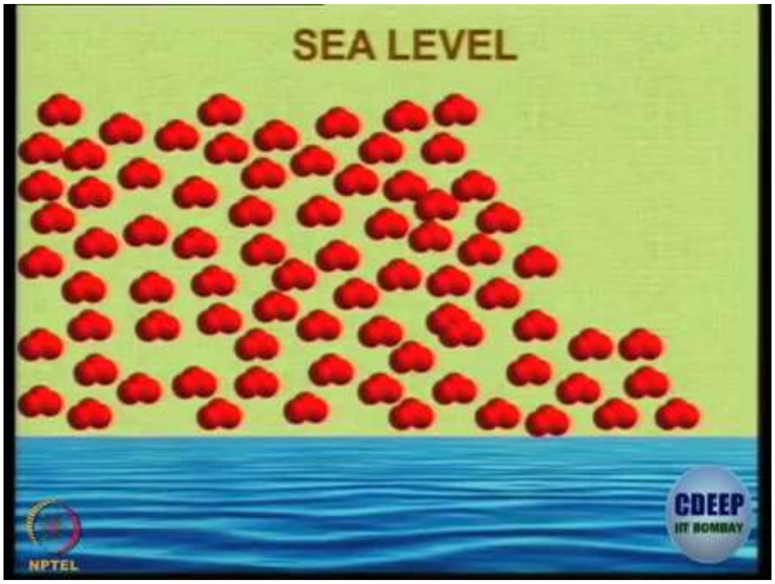

So this is just a small explanation very simple explanation so, at low altitude at sea level you have many higher density of air you have many more molecules of air available right? At a higher level density becomes less so let us see the effect.

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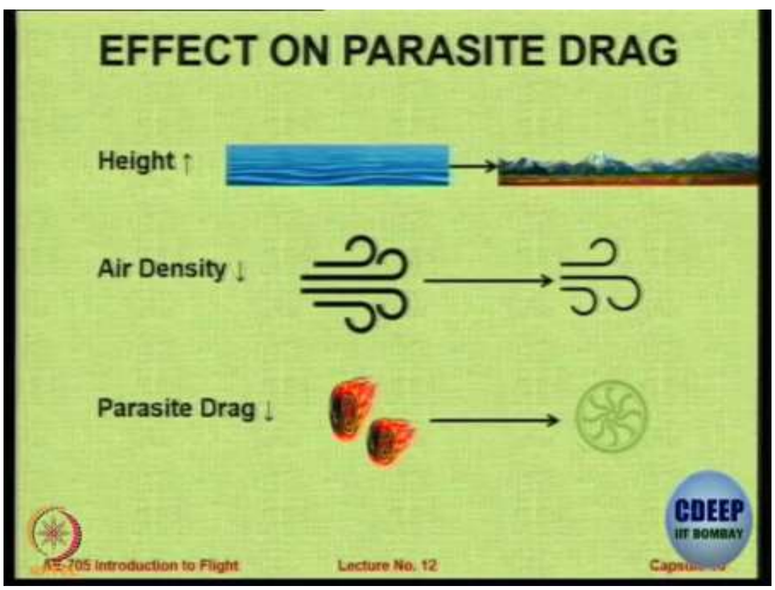

So as the height increases, as the air density reduces, so the parasite drag reduces. At higher altitude you have lower value of air density because density is lower the parasite drag is also going to be lower.

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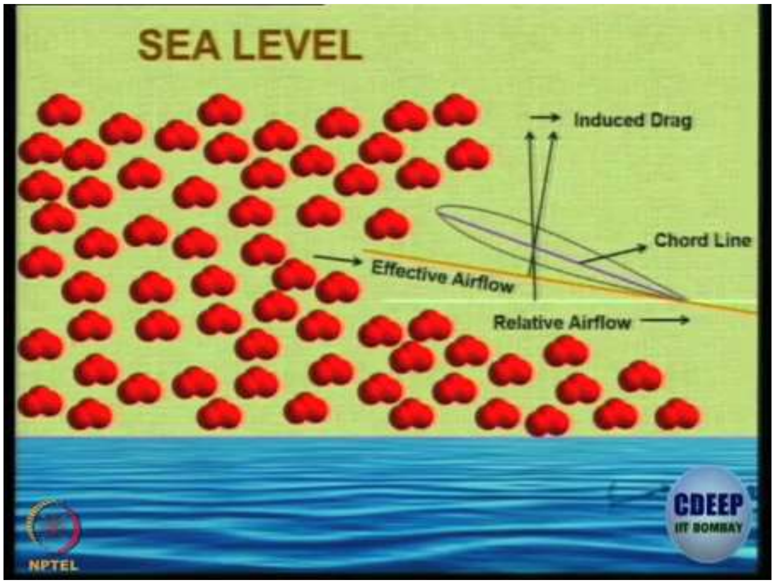

So, at sea level if you have wing which has got some particular relative flow you have some induced drag, an arrow which is because it is being pushed back.

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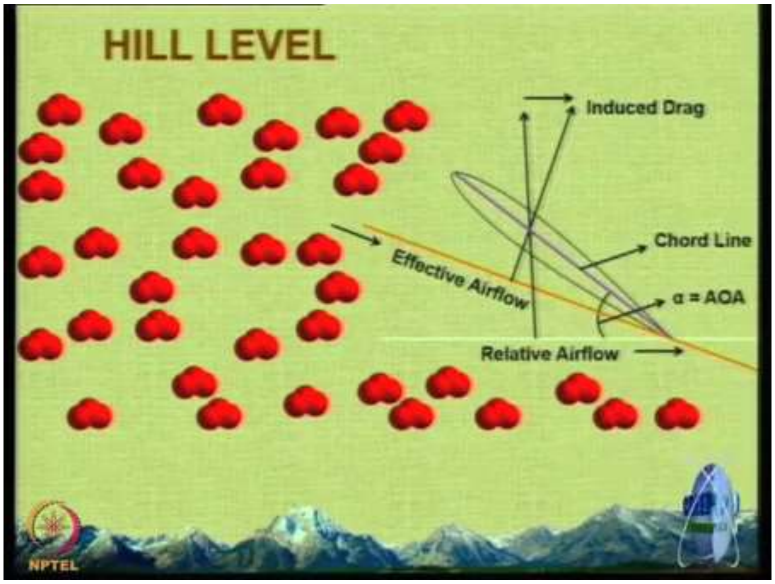

At higher altitude you will find that you have to fly at a larger angle because the density is less so what you have with you only is density and velocity, the two things that are available to you to change, ok?

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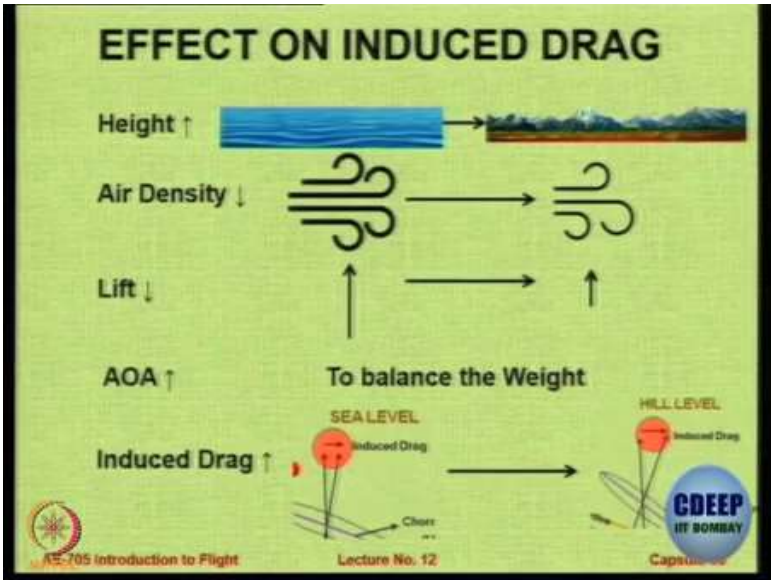

So, let us see the effect, as the height increases the air density reduces, lift reduces so therefore you have to make higher angle of attack to balance the same weight and therefore the induced drag is going to go up because you are going to at higher angle of attack.

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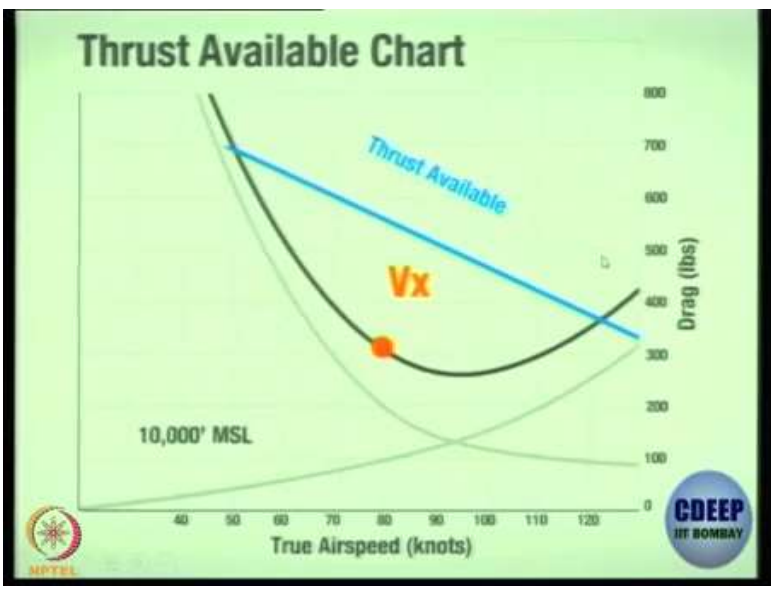

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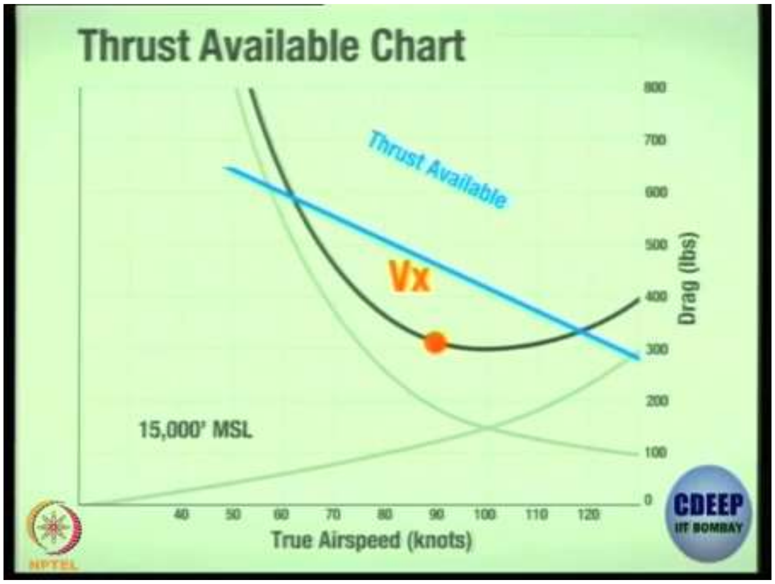

So, if you look at now what happens at various altitudes so you are at some altitudes 5000 meters, 10000 meters, so notice how the lines are changing. The thrust available line is coming down and the thrust required line is going up and tilting to right ok. So why does it tilt to right? For that you have to do the numerical calculations which we will do in the tutorial probably, to know how it changes.

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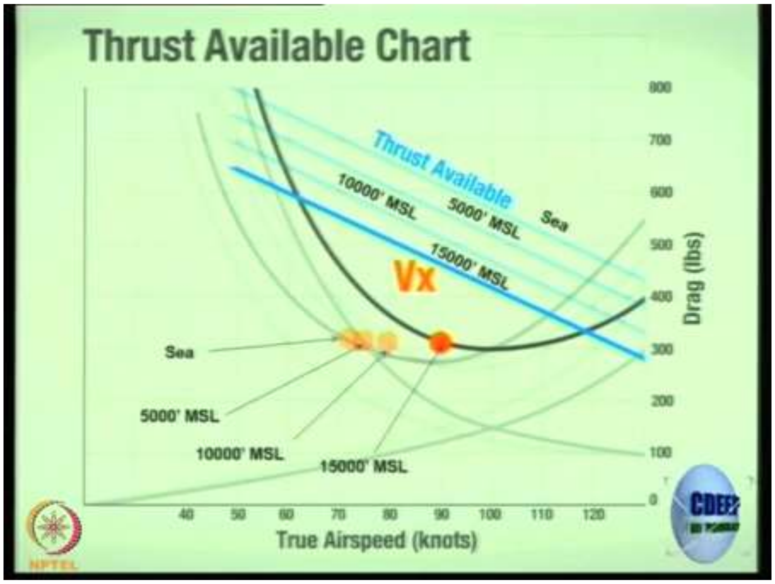

So the net important point is that the gap between the thrust available the blue line, the thrust required the black line this gap keeps reducing and the velocity at which this gap is maximum also keeps changing. So, at sea level you have that point, at a higher speed you have that point 10000, 15000. So, the numerical value of velocity at which the difference between the thrust available and thrust required is maximum increases or shifts as the altitude increases. So, you have to fly faster and faster to be at the maximum gap.

So now what will happen is, can you imagine a time will come or an altitude will come at which these two lines will be intersecting only at one point. So that velocity, is the velocity that you need to fly if you want to fly at a particular altitude and that is a ceiling because after that, the velocity, the velocity after that the thrust required will be more than the thrust available so you cannot.

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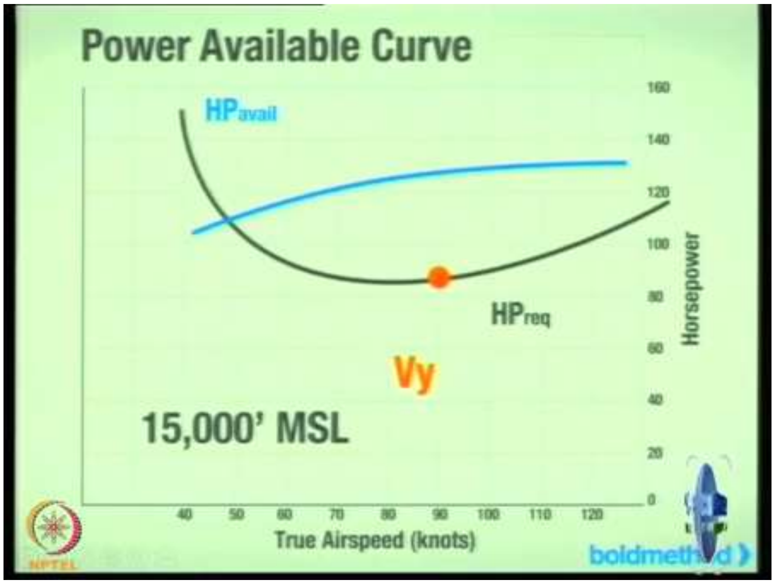

Now, the same thing we look at the power pattern now, so in the power pattern also, if you see the power available is reducing. In the book by Anderson, the power available was shown as a straight line and I said it should be simplification. This is the real story and it is not a straight line, it is slightly a curved line which we ignore and make an assumption that it is a straight line.

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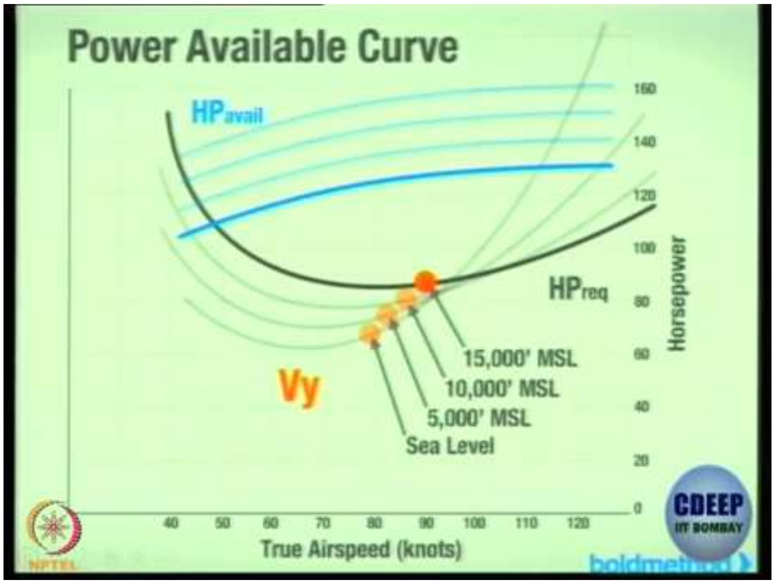

You can see now, that a similar story is happening and once again the velocity at which the power gap is maximum is also increasing slightly. So once again the time will come when the power available is equal to the power required, you cannot go above that, ok?

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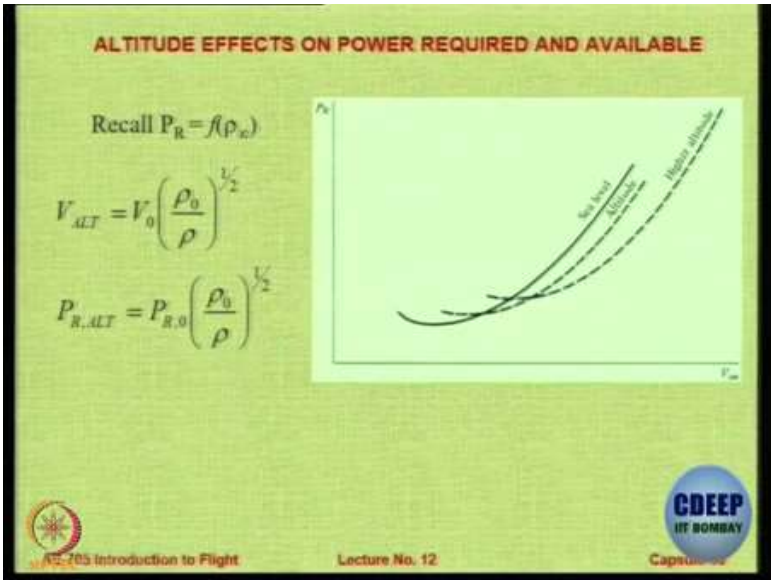

So, this is just to tell you how the power curve changes. So, one simple approximation will be that the power required at an altitude is the power required at the sea level times the root of the density ratio. This is the simple approximation and many Engines follow this particular rate also.

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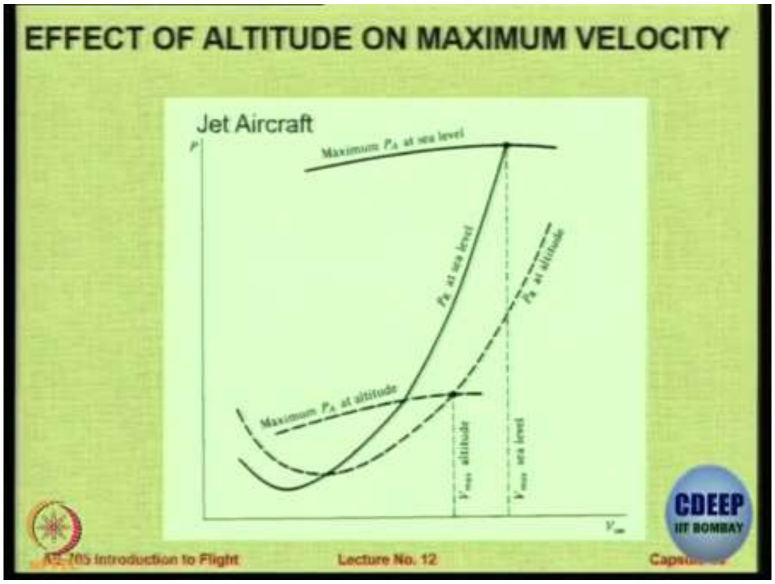

And, once again from the same textbook I have copied and included here charts which are similar to what we saw. So, you can see that at lower altitude, this is the power available, this is the power required, the maximum occurs at this particular speed. At higher altitude, sorry, at sea level this is the value. So at sea level you have a velocity and at altitude you have a velocity. So, the maximum velocity at which you fly, it is the function of the difference between the power available and power required.

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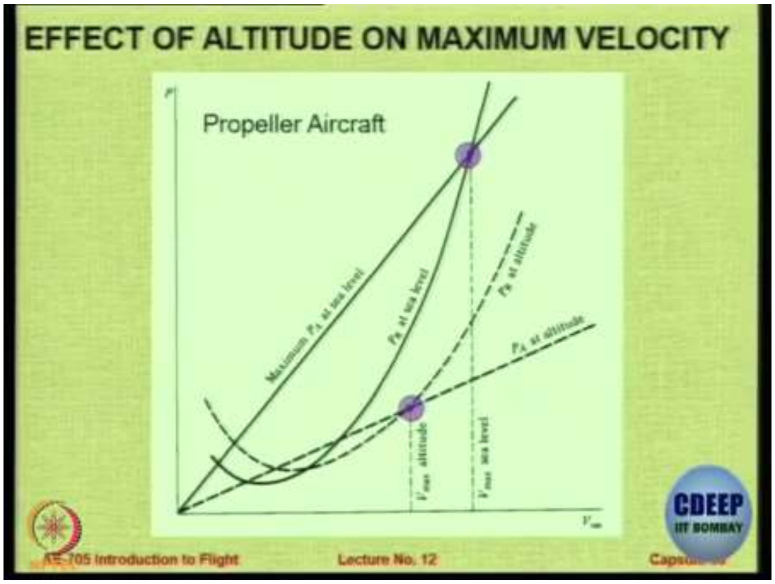

And the same thing for the propeller aircraft, ok.

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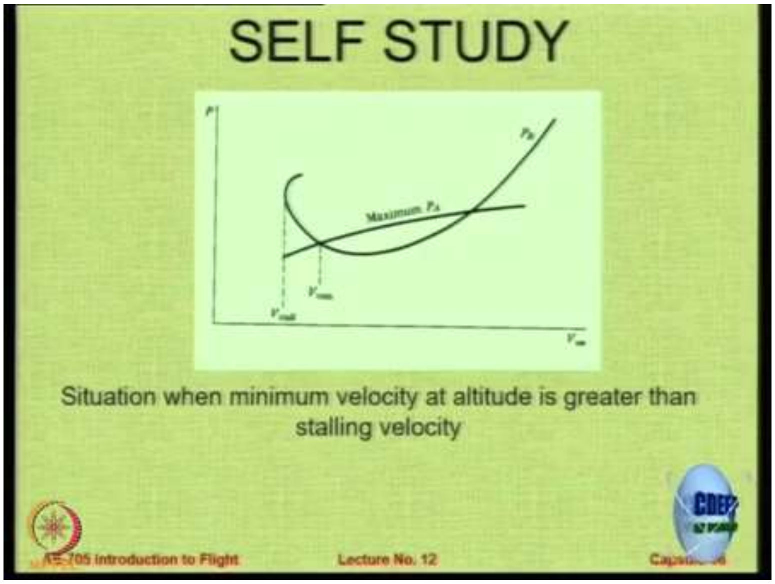

Now, this is something which I want to leave it to you for self-study. Actually, we have already discussed it, this is the ceiling, ceiling calculations ok.