Design of Fixed Wing Unmanned Aerial Vehicles

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Lecture – 23
Tutorial 3

Now, we will discuss the solution with explanation of assignment 5 and 6. They have already explained, we have already given the solution of assignment 1, 2, 3, and 4 and also we explained about the solution of assignment 1, 2, 3, and 4. So, let us solve the assignments 5 and 6 so in assignment 5 you have it is given that drag polar

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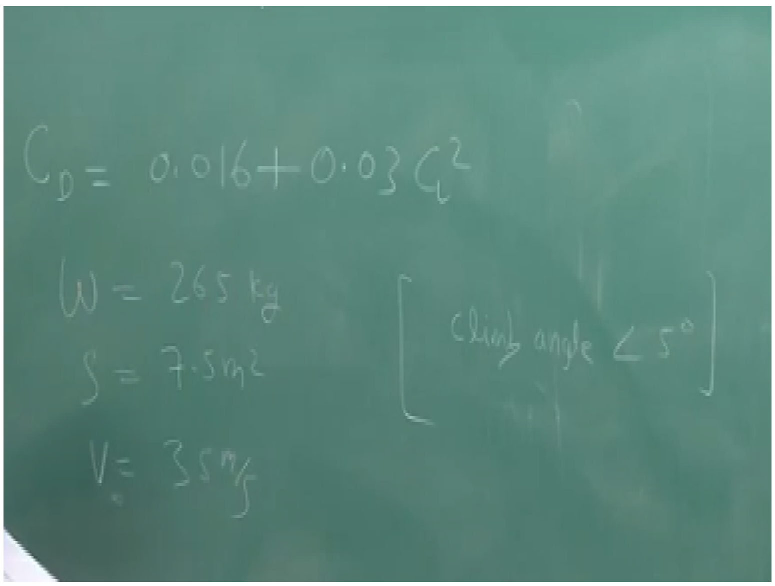

CD= CD0 which is =0.016 and+ CL is CL square KCL square, in this K is 0.03 CL square. Rate of the UAV is also given 265kg wing area of the UAV is also given it is 7.5 meter square and UAV claiming speed is V infinity is 35 meter per second. And it is also given those small angle assumptions. Climb angle <5 degree.

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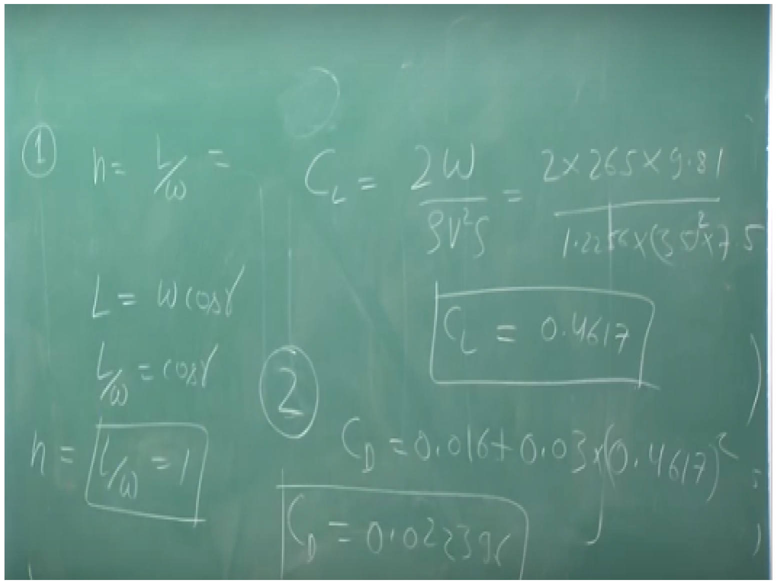

So, in the first question you have to find the load factor which is nothing but lift /weight. So, at cruise condition lift will be the weight it will be the one but what will be the in climb condition. So, when you are climbing then you lift will be balanced by w cos gamma lift/weight= cos gamma. But you know that angle is given < 5 degree so cos gamma is approximated as 1 and sin gamma is approximated as 0.

So, cos gamma will be 1 so your answer will be 1 okay. And in the second equation you have to find the CL value. CL value you are very familiar with this equation 2w /rho v square*S. So, weight is given as 265 and you have to convert in newton multiplied by 9.81 mean sea level density is given 2.556. If it does not give, then take the mean sea level density v is nothing but 35 and your area is given 7.5 so CL will come 0.4617.

So, this is your left co-efficient of the second question. In third question you have to find the value of CD. You know the CD sorry in third question you have to find the value of CD. So, you know the CL just put the CL equation in one you will get the value of CD. So, in third question CD will be 0.016+ 0.03*CL just put CL value 0.4617 so square it you will get CD= 0.022396 this will be your CD value.

So, in third question you have to find the value of sorry this is your second question CD value. So, to get the CD value you have to find the CL value. So, your CD will be the 0.022396 and your third question will be what will be the thrust required.

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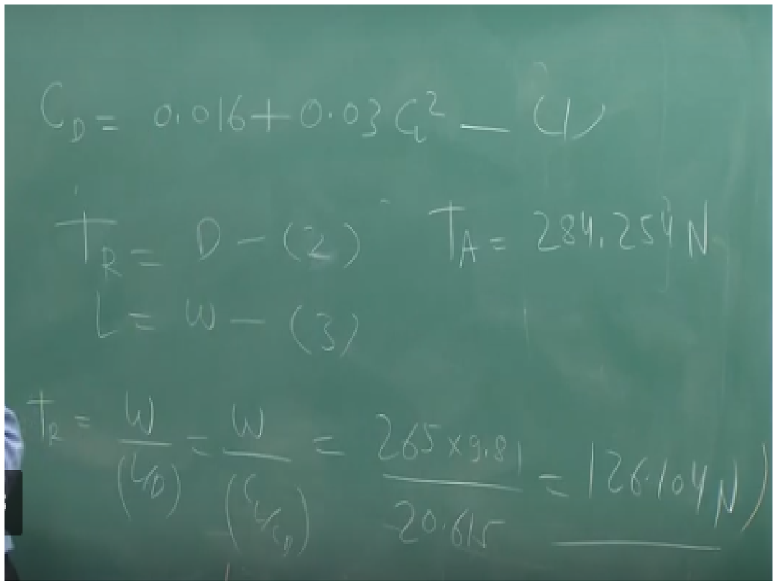

So, you know it is already given that climb angle is small so you can approximate as cruise level flight thrust=drive thrust required and lift=weight equation 2 and equation 3. If you manipulate equation 2 and equation 3 together you will get thrust required=w/L/D, you can also write w/ CL/CD. So w you know 265 to convert into newton / what is your CL/CD. CL you know .4617 and CD you know 0.22396 when you divide CL/CD you will get approximately 20.615.

So, your thrust required will be 126.104 newton and this will be your thrust required. And in the fourth question if the thrust available is given 284.254, the thrust available is given=284.254 newton. Then the climb angle in degrees will be we have already assumed that the climb angle is <5 degrees so let us check how much it is coming.

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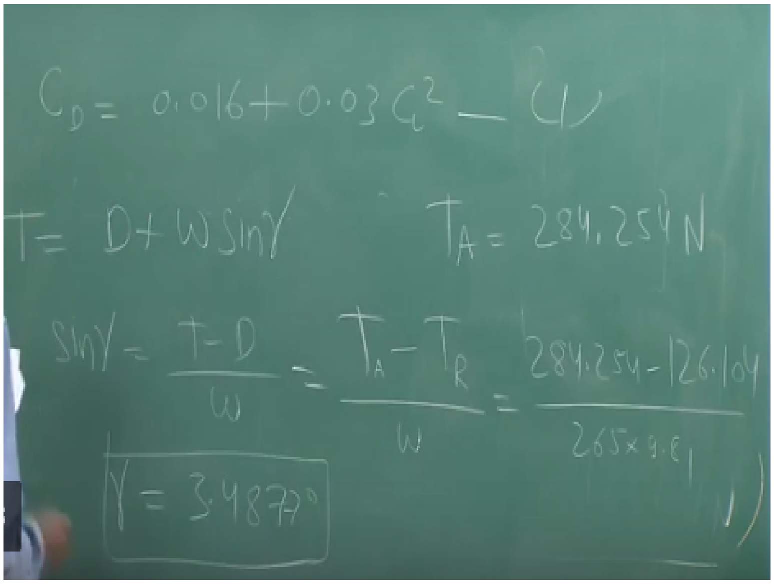

So, in climb if you balance the force then the thrust is nothing but D+w sin gamma, right. So, sin gamma will be T-D/w right. This is nothing but thrust available-thrust required/w. So, thrust available is given 284.254–thrust required you have found out 126.104/265*9.81 sin gamma is this much. When you take the inverse both sides you will get gamma=3.4877 degree. This will be the climb angle okay here gamma is the climb angle.

So, this will be the answer of 4th question. So, in 5 th question you have to find at which rate the air craft is climbing means you have to find the climb rate.

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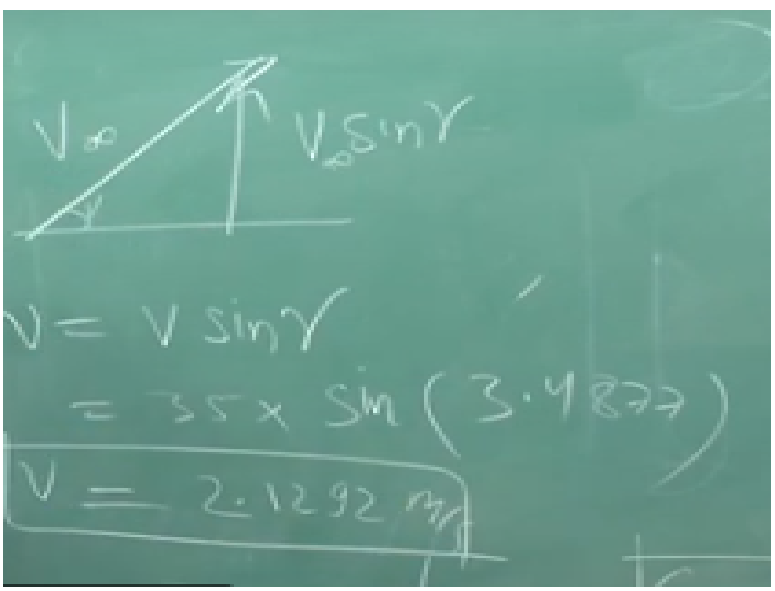

You know your velocity vector is in this direction v infinity so this is gamma so this component will be the v sin gamma or v infinity sin gamma this will the climb rate of climb you can denote it as small v = v sin gamma v you know already it is given 35*sin gamma sin 3.4877/no not your answer will come 2.12 meter per second. So, this is your climb rate this is your fifth.

In sixth question you have to find the fuel fraction from 1 to 5 the data is given and from 6 to 10 the data is given. So, you have to use that data in order to get the answer from question 6 to 10. So let us write the data which is given.

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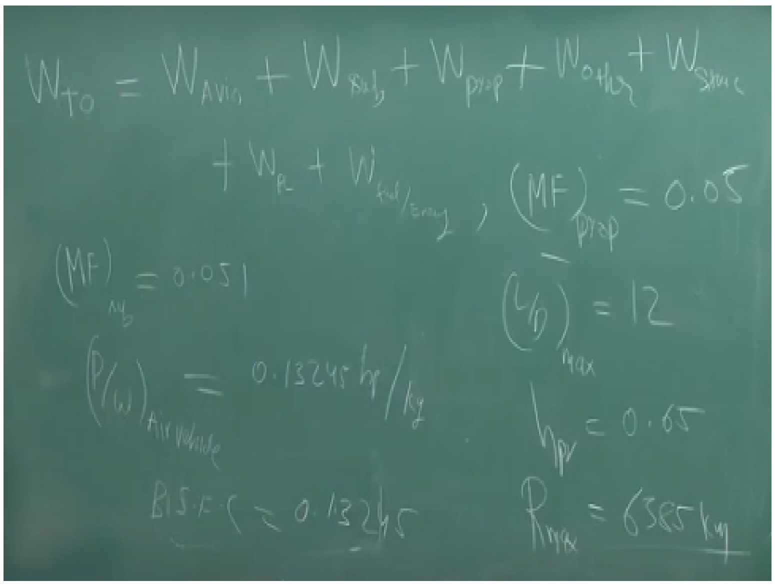

So, first this equation is given total weight of the air craft air vehicle is nothing but weight of the avionics w avionics w sub system w propulsion propeller w propulsion system rate w other w a structure w payload w fuel or energy. So, you know in air craft pay load will be there fuel will be there propulsion system will be there structures will be there your avionics software and all this will come into this your hydraulics.

And all will come in this w others are bias extra things you can take in this W others. With this information it is also given the mass structure of structures. How much percentage with respect to the total air craft weight, the structure weight is given 0.051 and your power to weight ratio of air vehicle is also given which is 0.13245 hp per kg. And break a specific fuel consumption is also given B am writing as S specific FC fuel consumption is 0.2265 kg/hp hr (As per video)**.**

And mass friction of propulsion system which is 0.05 L/D max is also given 12 at cruise condition. Propulsive efficiency is given 0.65 and maximum range is also given 6385 kilometer and it is given that all avionics w avionics payload and other having weight=50kgs means w avionics+w payload and w others=50kgs w subsystem w propulsion system w structures w fuel if you divide it by w take off you will get mass friction of propulsion which is given.

W structures/w take off mass friction of the subsystem are given okay. And mass friction of the fuel w fuel/w take off you have to find. So, suppose that we know that w fuel/w take off in this equation then we can get the take-off weight. So, everything we know what we want to know that w fuel/w take off. So, UAV is given okay R max is given, if you know the R max equation range is given so you know the UAV propeller power right.

So, you can use the range formula in order to get the mass fraction of fuel fraction of this system.

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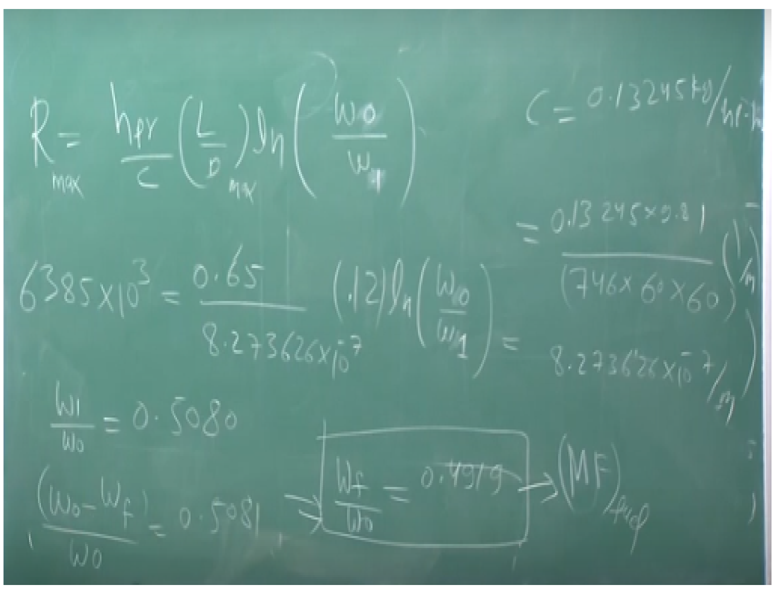

Using this formula R= eta p r/ c c is the break excess fuel consumption which is given 0.13245hp kg per hp alright this is kg/hp hour okay. So, you can use this formula L/D ln w0/ w1, w0 is the weight when all the fuel gets consumed and w1 is the initial weight. This is w1 and w0. w0 is the total weight of the air vehicle and W1 is the weight when all fuel gets consumed. So, R max is given, if this is the R maximum this also will be the maximum, okay.

So, you just put W of R max which is given 6385 meter to kilometer you have to convert into meter. Propulsive efficiency is given by .65 and C value is given in kghpr. So, here you can write C = 0.13245kg per hp hour. So, these things you can convert into SI unit so what you will get 0.13245*9.81, you have to convert into newton/1 hp=746 watt and hour if you convert into meter minute this will come 60 minute*second again the 60 will come.

So, if you will finally get the unit as a 1/meter, okay. So this value will come out 8.273626*10 power -7 per meter okay. So you can put this value 8.273626*10 power -7. L/D max is given 12 ln w1/w0. So you have to take at least 5 to 6 digit in order to get the correct answer. What will be the w1/w0? It will come 0.5080, okay this is w0 and this is w1. So, first you will get fewer and this w0/w1 if you reciprocate this you will get w1/w0.

And we know that w1 nothing but total weight-weight of the fuel, because already I told you that w1 is the weight when all the fuel gets consumed * 0.5081 if you take this term separately w1/ w0 you will get w1/ w0 as 1- 0.5081 which will come as 0.4919. So, this is wF/ w0. So you can say this is the mass friction of fuel, okay. So, you can use this formula in order to get the mass fraction.

So, in first question it is asked to find the value fuel of mass fraction which is coming 0.4919. In the second question you have to find the total takeoff weight so see this one these things and this if you combine w avionics w others+w pay load it is given 50 kg. And this in terms of mass fraction ratio these in terms of mass fraction ratio and this in terms of mass fraction ratio and this in terms of mass fraction ratio you got. So, this equation if you manipulate then what you will get?

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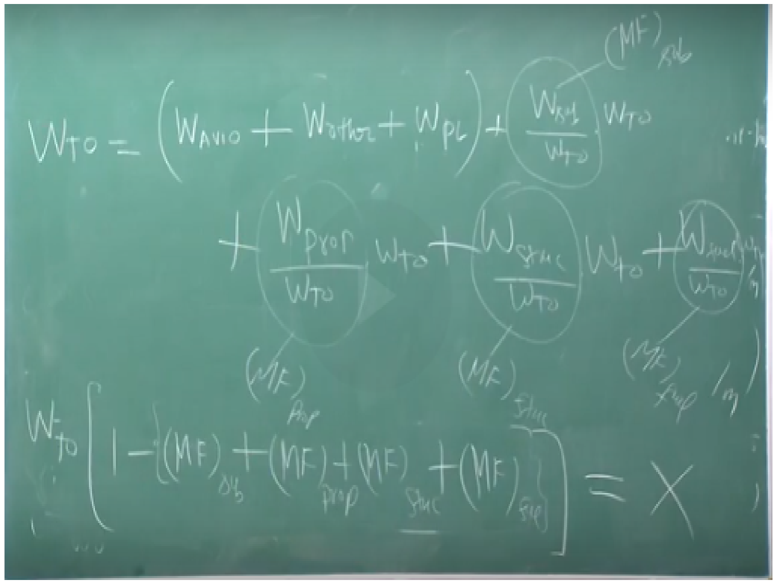

So, you can write w take off these three first so this will be w avionics first you write which is given w avionics+w other+w pay load this write separately. And next is w sub system so w subsystem you can write w subsystem/w take off *weight of the take-off okay+w propulsion you can write w propulsion/w take off *w take off+w structures you can write w take off*w take off + what will be the last w fuel/w take off *w take off.

So, this is mass fraction of propulsion system this is mass fraction of structures and this is mass fraction of sub system and this is the mass fraction of fuel okay. So, bring this this and this term in this side what you will get w take off will be the common then 1- mass fraction of sub system again you can put one bracket+mass fraction of propeller propulsion system mass fraction of structures+mass fraction of fuel.

You can complete this bracket this and = w avionics+w other+w pay load let us make it x okay. so you can write w take off separately as w take off=x is nothing but 50 kg.

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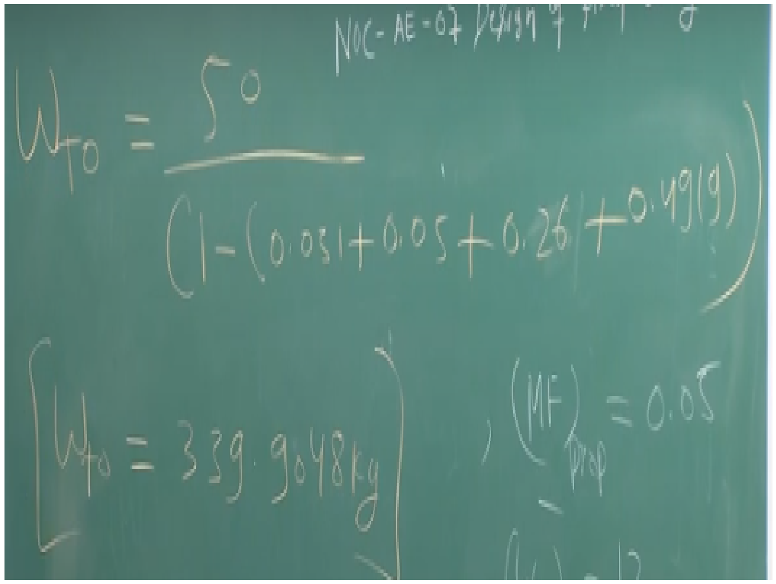

It is given w avionics + w other + w payload 50 kg/1-mass fraction of the sub system which is given mass fraction of the sub system is 0.051+mass fraction of the propulsion system 0.05+mass fraction of the structures 0.051+mass fraction of the fuel you got 0.4919 okay. Let me check 0.051 0.26 mass fraction of the structures is given 0.26 okay so 0.260, .490, .051 okay. And this is 50 so your w take off will be 339.9048 kg this will be your answer and next question you have to find the rate of the power plant so when deletion is given to you.

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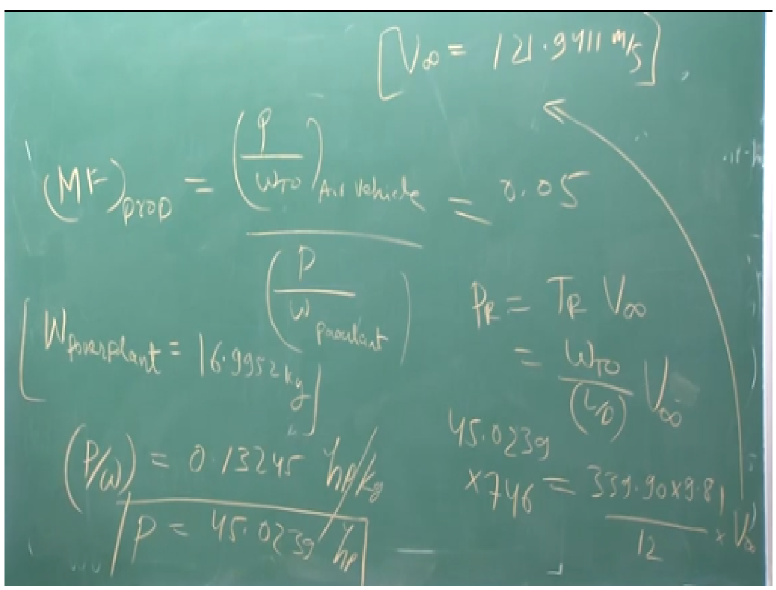

Write mass fraction of propulsion system= p/w take off of air vehicle/p/w power plant this p p will get cancelled w take off you already know mass fraction. You already know this is nothing but 0.05 if you put w take off is it is coming 339.9048 you will get the w power plant=16.9952 kg this will be the answer of your eighth question. So, in ninth question you have to find the peak power of the air vehicle.

What is the power maximum power engine having? so p/air vehicle is also given 0.13245 hp per kg which is given to you so multiply by w take off you will get p=45.0239 hp. So, this is answer of that question which is question number 9 suppose that with this power UAV is flying then what will be the speed in next question you have to find so you know power required is nothing but thrust required*v and you know thrust required is w take off/L/D at cruise condition.

Okay and if your power required and power available is equal this power you are flying with maximum power which is here 45.0239 which we have found out. So, put this p power 45.0239 this mean you are flying at a maximum power you are using maximum power from the engine. So, this is hp you can multiply by the watt you will get the answer in watt w take off is you have found known already.

339.90*9.81 to convert into newton/L/D is given 12 and v infinity. So v infinity will come from here v infinity will come 121.9411 meter per second. If you are flying with this power condition your speed will be the 121.9411 meter per second so this is all about the assignments five. So, last we will go to the assignment 6 for an electric power fix in UAV with extended parameter and mission profile is given so the mission profile is given to you.

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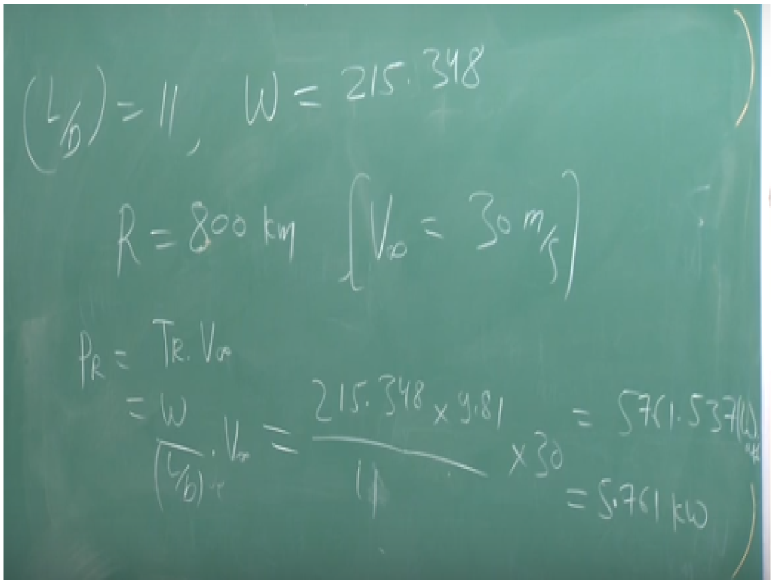

So, the mission profile is given to you your L/D is 11 your weight is 215.48 rate of UAV range is 800km and the speed which is flying the UAV which is flying at this speed and hint also is given that means you have to consider the UAV is flying at a cruise condition. So, in this first you have to calculate the battery power required so what will be the battery power in kilowatt required to complete this mission.

So, you know that power required is nothing but thrust required * velocity okay. Thrust required = w/L/D*v infinity w is given 215.348/L/D is also given 13 okay L/D is given 11*9.81*30. So, your answer will be 5761.537 watt so in kilowatt your answer will be 5.761 kilowatt okay this will be your power required 5. okay. So, in second question you have to find the endurance so that you can easily find out.

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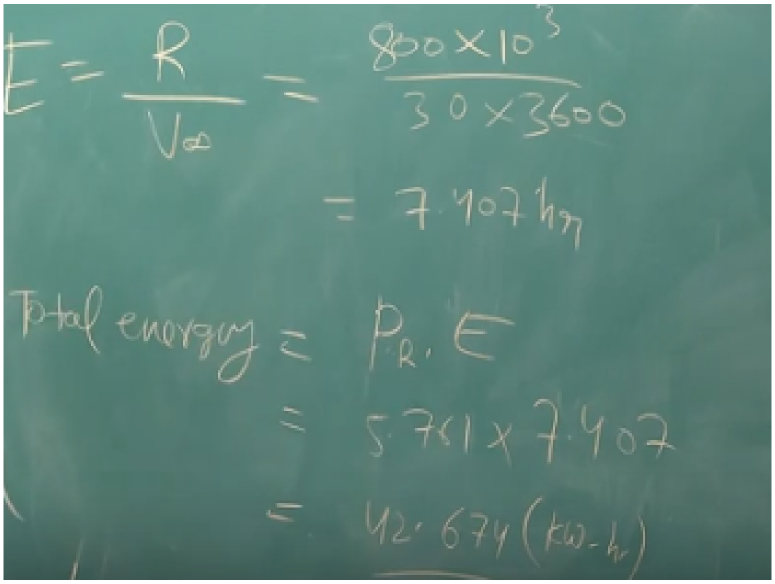

Endurance is nothing but range/velocity so range is given 800 kilo meter you have to convert into meter/speed is given 30 and this is in a it will come in second multiply/by3600 you will get endurance in a watt so that will be the 7.407 hr. So, this will be your endurance and in third question you have to find the total energy in kilowatts supplied by the battery. So, in kilowatt hour.

So, total energy will be what you got the power required is multiplied by the endurance power required is 5.761 kilowatts*endurance is 7.407 and your answer will be 42.674 kilowatt hour. So, that will be your total energy so how much the battery will have if the total energy if you want endurance 7.407 and you want range is 800 kilometer then how much battery weight will be required.

So, the battery weight depends on the which battery you are choosing especially density is required in order to get the battery weight. So, a specific energy of the battery is given.

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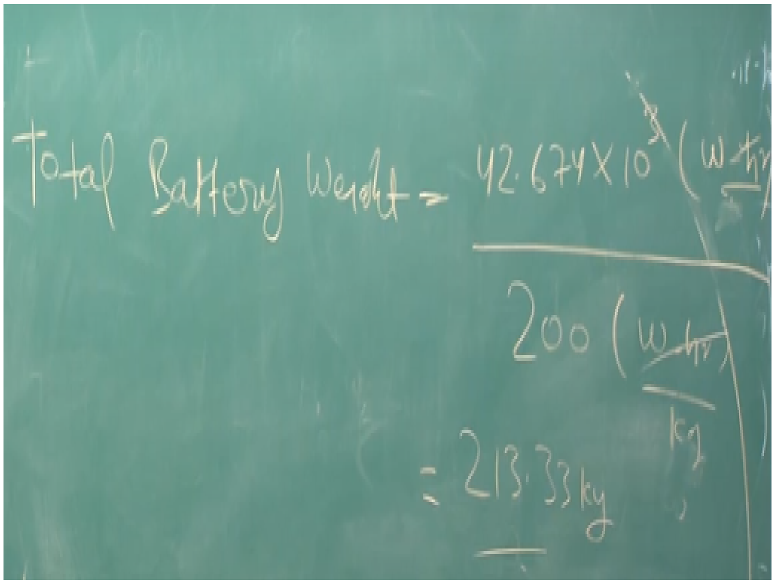

So, total battery weight is will be total battery weight= total energy is you got 42.674 kilowatt hour and converted into watt hour okay. This is unit is watt hour per only watt hour/this is total energy and a specific energy is given 200-watt hour per kg. This watt hour will cancel if you solve this you will get 213.33 kg this is the total weight of the battery. So, in the fifth question what is the necessary condition of the stable UAV. So, sir already explained you about the longitudinal estimate in case of CM0 CM alpha.

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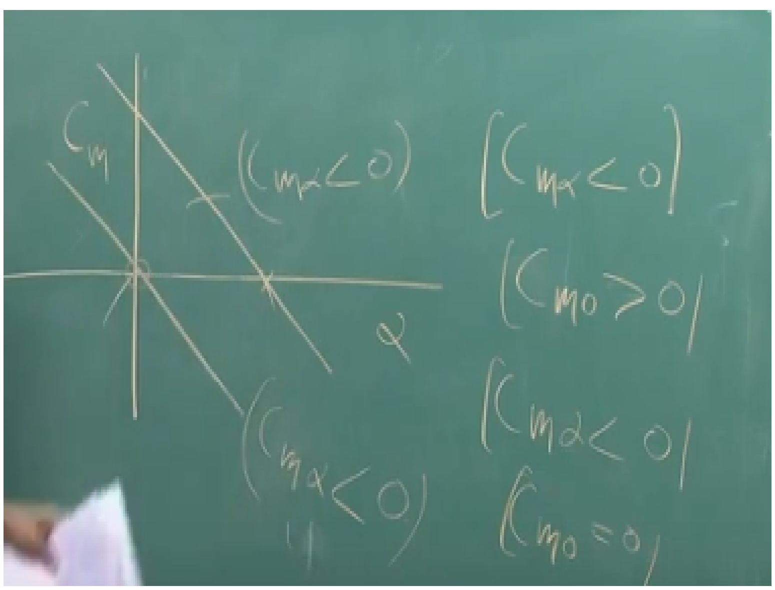

So, as you know that from this diagram you can say in you angle of attack is in x axis and pitching co efficient is y axis. So, this is your CM versus alpha graph for the stable UAV in this condition CM alpha < 0. So, this is the necessary condition in this case CM alpha< 0 but CM0 at alpha=0 CM is 0. In this condition also your aircraft is stable but you cannot trim the aircraft at positive angle okay. So, answer for this question your CM alpha will be < 0 okay.

This is the necessary condition of the stable UAV but in order to trim the UAV or a curve at positive angle of attack your CM0 should be >0. And in same question you have to find which condition hold the trim the a stable UAV at 0 angle of a time. So, this condition will be satisfied CM alpha <0 and CM0 = 0. If you have this two you can take trim the UAV at 0 angle of attack and in eighth question some airfoil is given like airfoil OFA and last one is airfoil S1223.

So, the comparison is given and x axis angle of attack is given and in y axis lift coefficient is given and the question is which airfoil will give the lowest speed.

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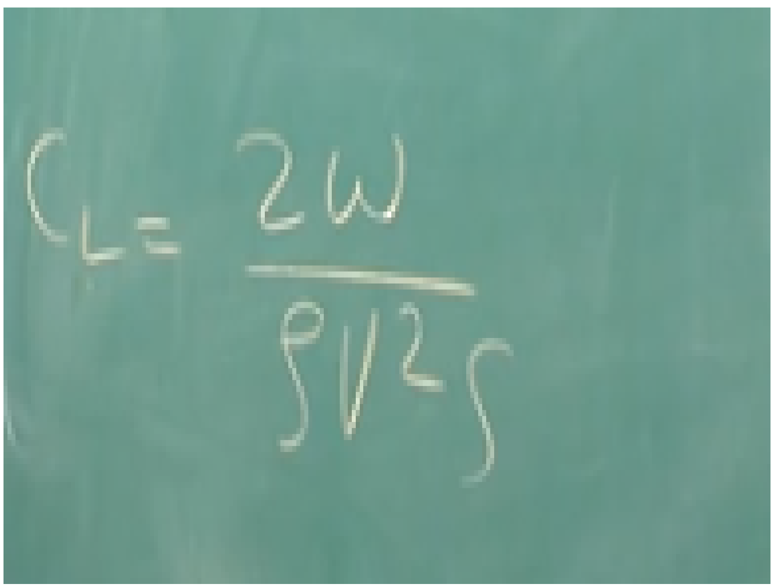

So, see if you write this CL=w/rho v square if your CL increases keeping all your parameter constant. if your CL increases then v will decrease. So, just pick the airfoil which has higher cl max so in this condition airfoil is 1223 will have the higher CL max so for that particular airfoil the stall will be the lower compared to all okay. And in ninth question a wing is made of symmetrical airfoil the pitching movement coefficient at 0 degree angle of attack will be.

So, you know for a symmetrical airfoil at 0 angle of attack the pressure distribution on the upper surfaces and the pressure distribution on the lower surfaces will be the same. So, there will be the no lift at a 0 angle of attack.

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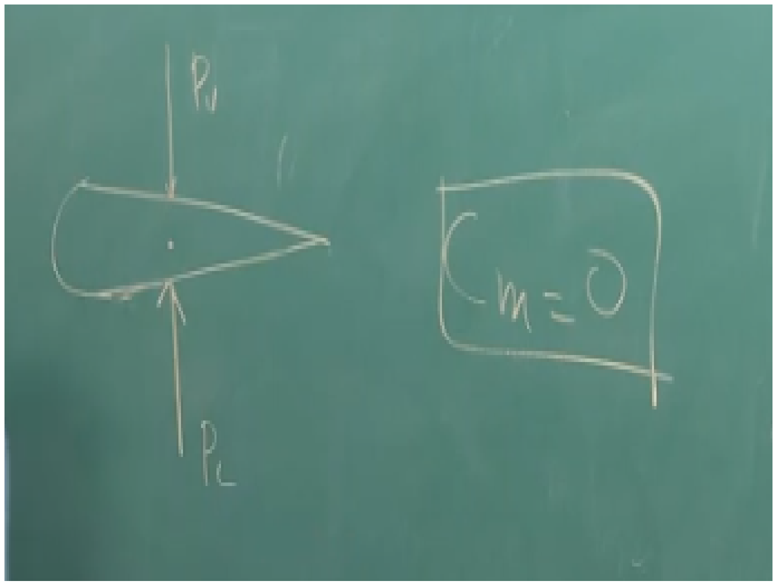

And also suppose this is the symmetrical airfoil your net upper pressure and lower pressure acting let us say PL and net upper pressure acting is PV so this will act at the same point. So, there will be the no lift and no movement so in this case CM=0 okay. And for the tenth question fur positively tempered airfoil produces in bracket it is also given moving is positive. So, you know that for the tempered airfoil the CMAC is negative.

So, obviously it will produce a nose down movement so nose down movement is negative so it will produce the negative switching movement about the aerodynamic center. So, this is all about the assignments problem we have already solved the ten problems. So, all the best for your exam thank you very much.