Fundamentals of Electrical Engineering

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Lecture – 64

DC Motors (Contd.)

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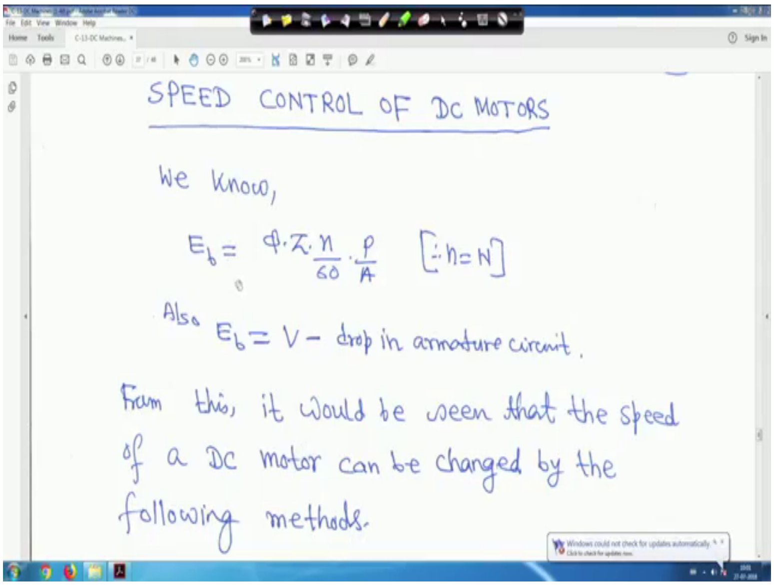

So this is that last part of this course right. So now, speed control of DC ~~motors~~Motors, you find things are quite simple. So, for example, we know that back Emf is equal to phi Z small n upon 60 into P by A somewhere I might have used capital n, but same thing that is why in the bracket it is written small n is equal to capital N. So, no confusion and E b you know that back Emf E b is equal to your V minus the drop in armature circuit, that is the voltage drop in the armature circuit that is i a into r a right.

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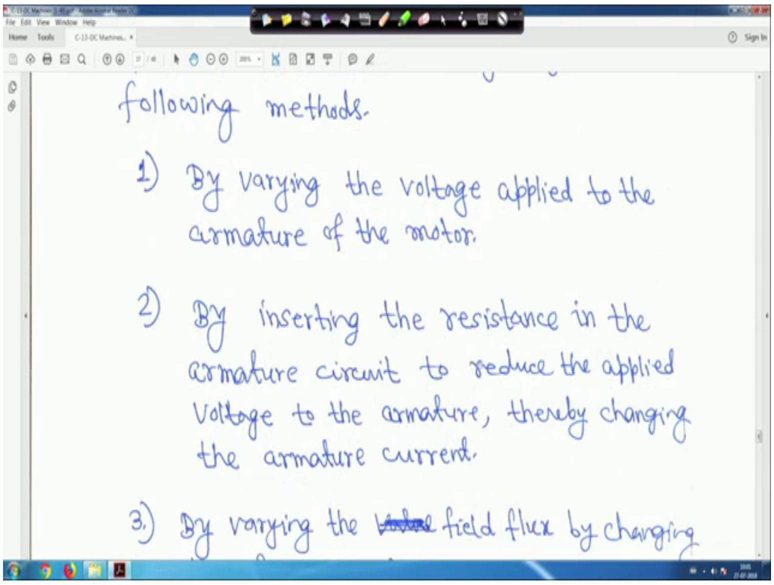

For this it would be seen that the speed of a DC motor can be changed by the following methods. One is by varying the voltage applied to the armature of the motor that is your ~~V;~~V; you can vary that applied voltage.

Another thing is by inserting the resistance in the ammeter circuit to reduce the applied voltage to the armature, there by changing the armature current right and number 3 is by varying the field flux by changing the field current, these are the 3different ways of changing the your what you call speed of the DC motor.

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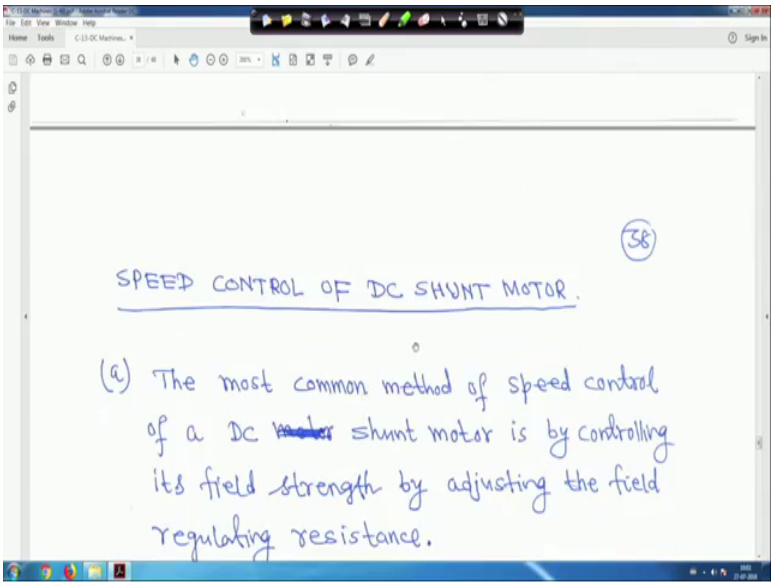

Now, if you look into that the speed control of a DC shunt motor right.

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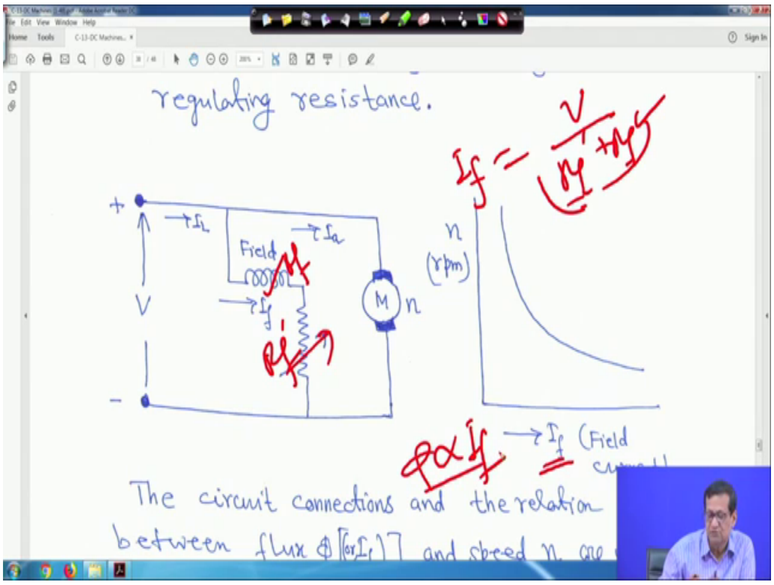

The most common method of speed control of a DC shunt motor is when controlling it is field strength by adjusting the field regulating resistance.

So, if you look into the circuit, that this is your field leaning and one additional resistance has been connected right, this is a variable resistance., if If you vary this resistance then your, what you call that your field current will vary.

For example, suppose this resistance is R f right. Suppose, this is your R f;. Soso, as say R f dash and this field resistance is R f right. So, when you try to find out what is field current;? Soso, I f will be is equal to V upon R f dash plus R f right, this R f anyway is fixed, this is the field resistance of the circuit of this of this filed winding and this R f dash actually, your what you call that variable resistance. So, if you if you can vary this resistance naturally, the field current will decrease right because, you are adding some resistance field current will decrease.

So, in that way your, what you call; that means, your flux is proportional to the filed current. So, naturally that your what you call that flux also will decrease right., but But in that case, we will see the characteristic, how it is if field current decreases speed increases., if If field current your increases sorry, if field current your increases; then flux also your increases right in that case, opposite will happen. So, and field basically I f actually field current phi actually proportional to I f right. So, this you will always keep it in your mind.

So, in that case in that case what will happen? We know this the circuit connections and the relation between flux or phi or I f this can be phi or this can be I f because, flux is proportional to I f and speed n are shown in figure above.

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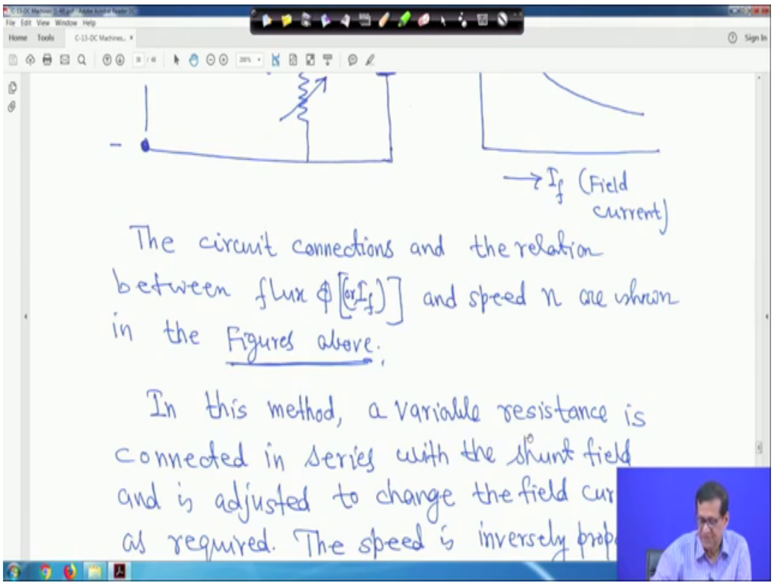

In this method a variable resistance is connected in series with the shunt field that is that is in this diagram, this I showed you this is the diagram right.

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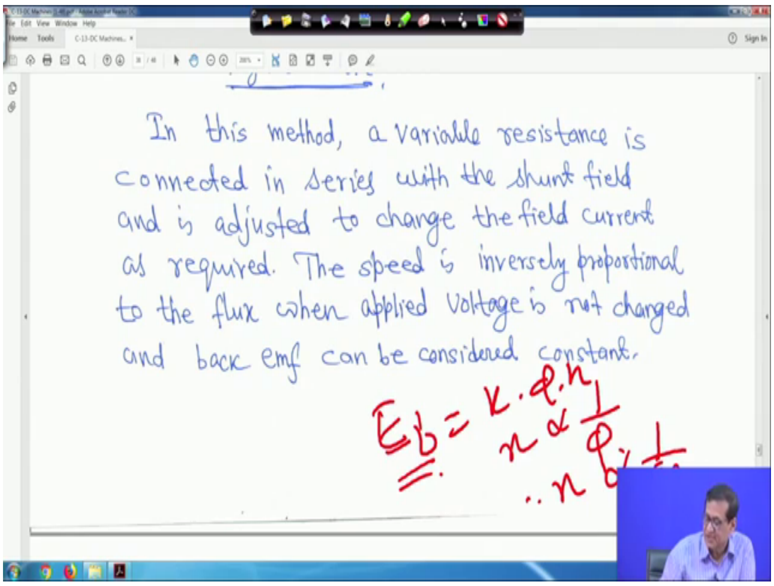

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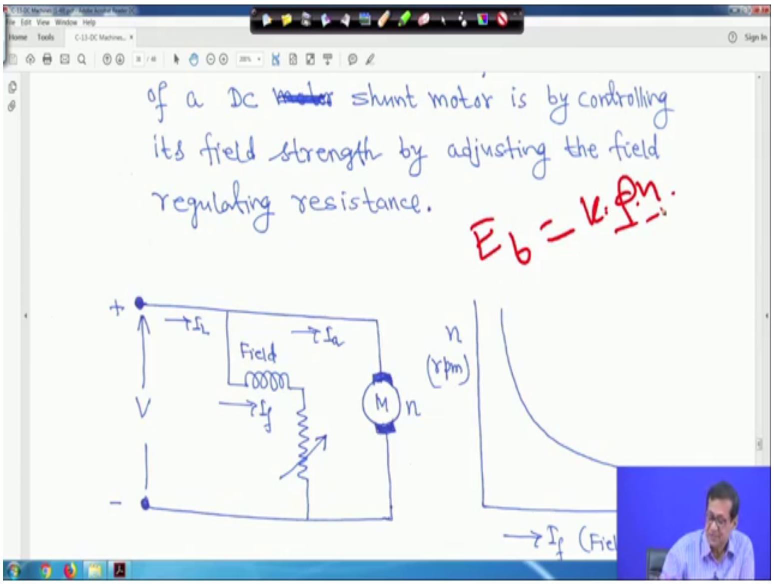

So, this speed is actually inversely proportional to the flux, when the applied voltage is not changed and back Emf can be considered constant that means, this equation.

Your this equation, we know this equation that your E b is equal to that back Emf is equal to write your K your K into your phi into n right.

So K is the constant and this is the flux and flux proportional to the i I; if the your what you call that your field current. So, we know this. So here, it is your what you call this is the expression, this is that your E b is equal to this expression right and if your E b is equal to then K into phi into n right. So, here it is written that field the speed inversely proportional to flux, when applied voltage is not changed and back Emf can be considered as constant.

That means your E b back Emf is equal to K into phi into n right. So, if you applied voltage constant then E b, if you can make constant then this then what will happen that n actually, inversely proportional to the your flux right. So, flux is proportional to I f; that means, n is inversely proportional to I f right; that means, if field current increases n decreases and vice versa. So, that is why that is why this characteristic is looks like a your what you call like this one like a rectangular hyperbola right.

So, this is your n rpm and this is your field current right. So, this is the characteristic.

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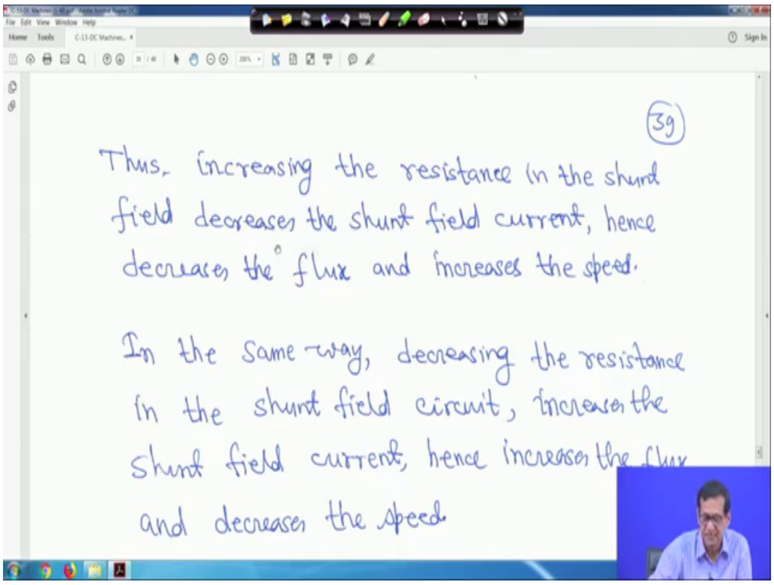

The next is your, thus increasing the resistance in the shunt field decreases the shunt field current hence, decreases the flux and increases the speed because, inversely proportional to it. ~~in~~ In the same way, decreasing the resistance in the shunt field circuit increases, the shunt field current hence, increases the flux and decreases the speed right, this is one method.

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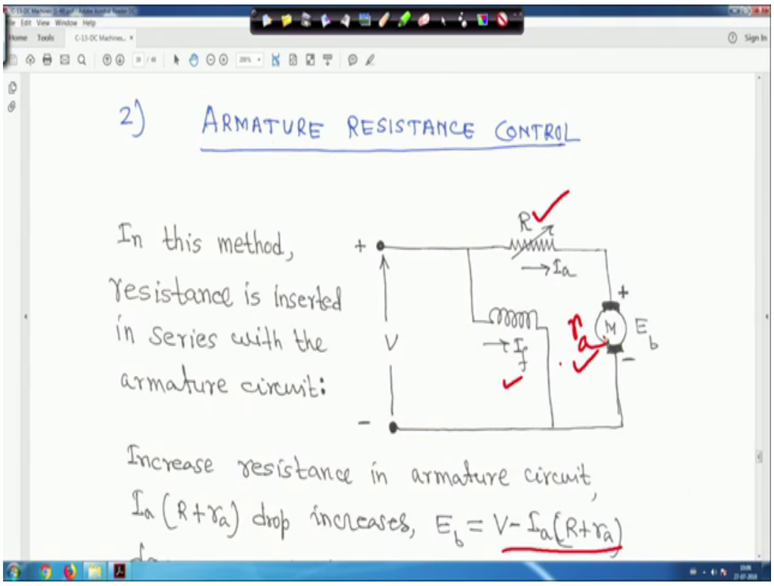

Another is the that armature resistors resistance control method, in this method resistance actually here, it is inserted in series with the armature circuit with this is your R, this is your R that resistance is inserted here and armature resistance I mean, it is your R a small r a right and this is the field current here nothing is there. So, increase the resistance in the armature circuit means the, this is your back Emf. So, if you apply in this circuit kvl you will get E b is equal to V minus I a into R plus r a, r a is the armature resistance right.

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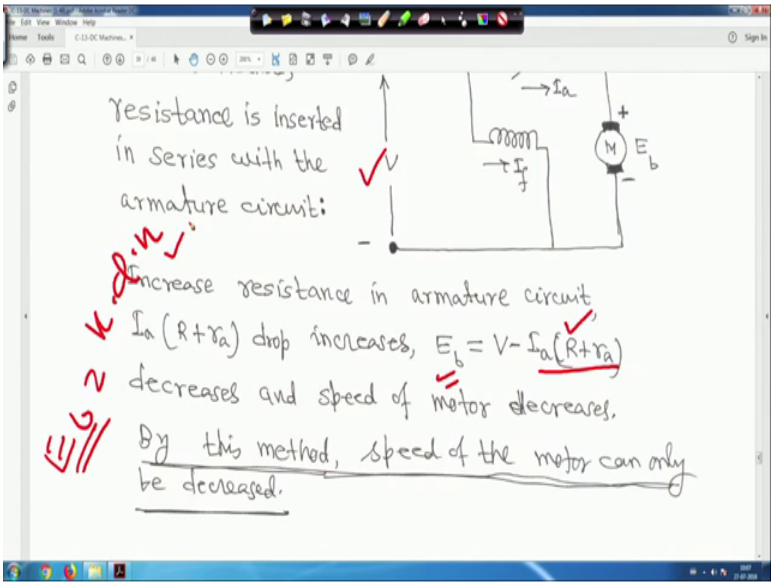

So, therefore, increase the resistance in the armature circuit I r a that that is your at this if you increase this capital R right then drop increases. ~~therefore~~Therefore, E b will decrease right and speed of the motor actually, decreases because, back Emf because your, in this case your E b back Emf is equal to K into phi into n right. So, what is happening here? That because, we have inserted that resistance R. So, this drop will increase therefore, E b will decrease.

So, in that in that case, your field current I f remain constant because, nothing is connected here because, this voltage V is remains constant. So, in that case phi is also constant. So, your because of the decrease of E b n or speed also will decrease right. So, almost linearly it should vary. So, in this case what will happen the by this method? The speed of the motor can only be decreased, you cannot increase it, because of this your E b is decreasing right, you cannot this thing, you can because, you have added r. So, E b is decreasing. So, by this method only speed can be decrease right. So, this characteristic, you can easily draw.

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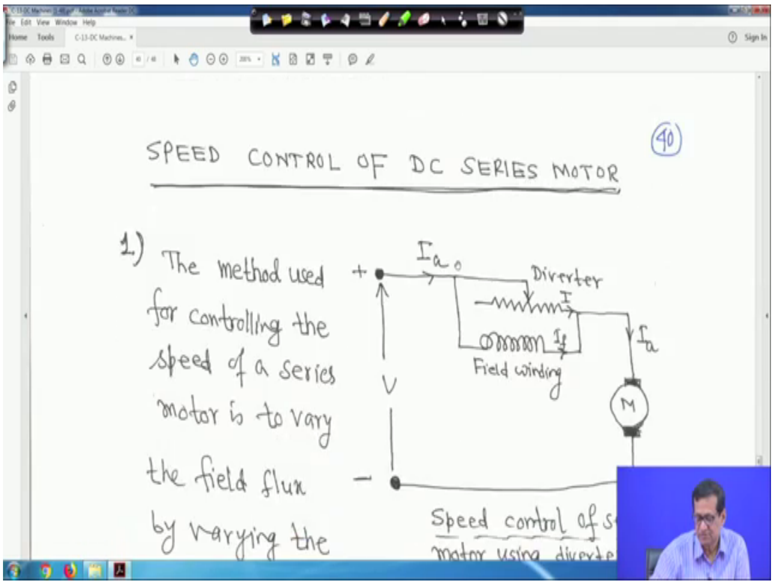

Now, second one is that speed control of DC series motor, now this is for shunt. So, nothing is there actually, you put a resistance R capital R and this because of that there will be voltage drop and field current remain constant. So, back Emf will decrease therefore, speed will decrease. So, this method you can only your, what you call, you can only decrease the speed of the machine.

Now, next is your speed control of a DC series motor, DC series motor actually field winding, we have seen is in series with the armature, but what is this that you connect 1 variable resistance, we called diverter that is in parallel to this field winding. So, the way you have studied, your simple parallel circuit for DC circuit analysis. So, as soon as and this is a variable as soon as you connect it, 1 part of the this is the total armature current, this is the total current I a right the same current is going and the part of the current, it will be flowing through this your I and part of the current flowing through the field winding right.

That means I f plus I a is equal to capital I suffix a right I f plus I is equal to I a.

So, by this way part of your basically, you can control this field current by adding a diverter, diverter means part of the current is diverted through this variable resistance, you can vary this. So, this speed control of a series motor, motor using diverter. So, this method used for controlling the speed of the series motor is to vary the field flux by varying the, your, excitation current because, the excitation current means the field current right.

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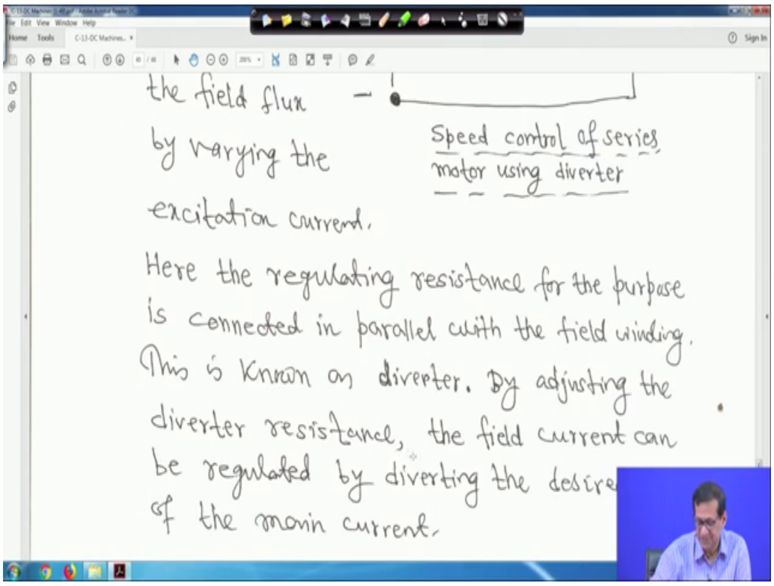

Here the regulating resistance for the purpose is connected in parallel with the field winding, this is known as diverter by adjusting the diverter resistance, the field current can be regulated by diverting, the desired fraction of the main currents. So, this is main current. So, part of the current can be flowing through this (Refer Time: 08:58) field current will you will decrease right.

So, now this is one way.

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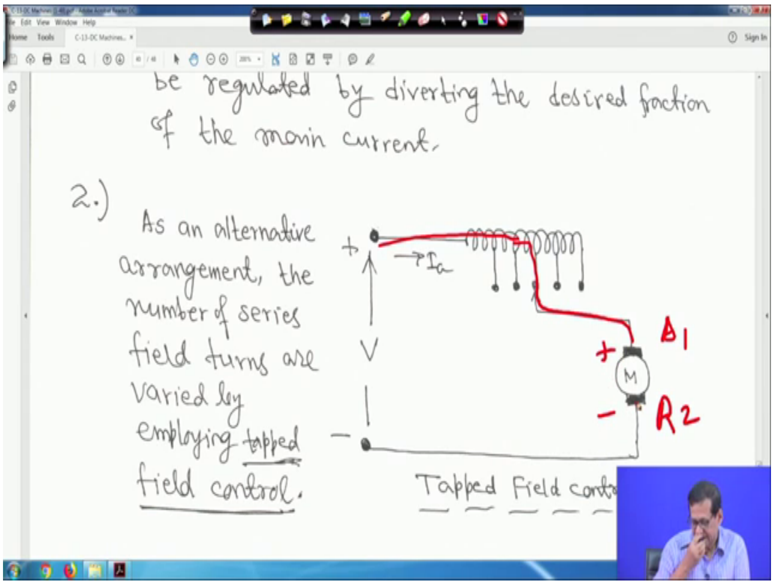

Another way is that as an alternative arrangement, the number of series field turns are varied by employing a tapped field control, in this case what happen? This is a series field, this is basically a series field many places tapped here, it is tapped if you connect this tap naturally, your what you call ~~this is~~ this is the path, it will follow that your, what you call this your what you call this is the path, this is the path, it will follow right and if you I have not marked here, it is A 1 A 2 right and this is plus minus right.

And ~~this your~~your, what you call by changing this by changing, this tap from here to here, what here to here, you can control the current through so the field right. So, this way also this is called tapped field control, this way also you can control the your what you call that your control the speed of the series motor right. So, details mathematics other thing just keeping at the first year level.

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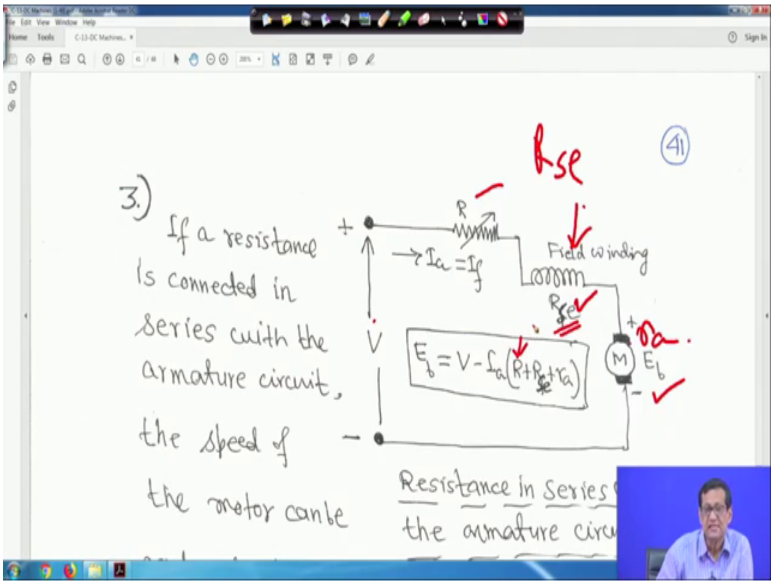

Now, number 3 that if a resistance is connected where, again series motor in connected in series with the armature circuit, the speed of the motor can be reduced by adjusting the resistance as the back Emf I mean here.; if If you put 1 resistance in series with the field winding because, both are in series I mean series with this is this your this one, this one, this resistance this armature is r a right. So, armature and this is R s e this is R s e right and this is R.

Therefore back Emf that E b the back Emf will be V minus I a into R plus R s e plus r a, this R s e is the series field winding resistance here series field winding resistance. So, in that case we are adding 1 resistance R right.

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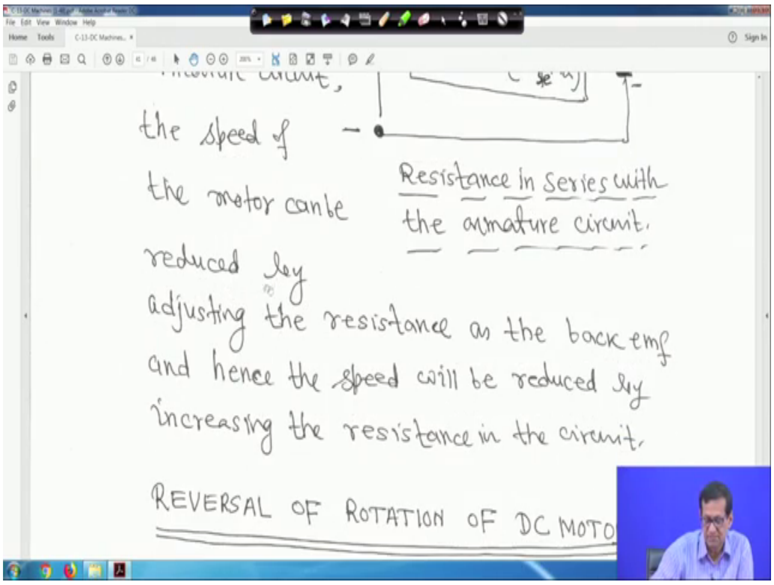

So, so resis[tance]-. Soso, in this case;. Soso, in this case also the speed of the armature can be reduced by R because, if you do so, the back Emf is getting reduced right. So, so by the adjusting the resistance of the back Emf hence, the speed will be your, what you call reduced by increasing the resistance in the circuit. So, if you increase the resistance. So, naturally your back Emf will decrease right. So, in that way speed can be reduced right. So, like your armature control in shunt motor.

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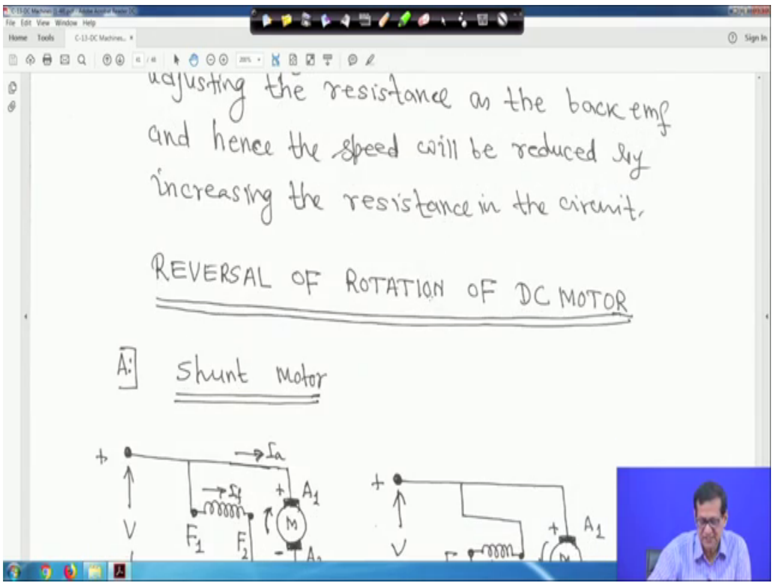

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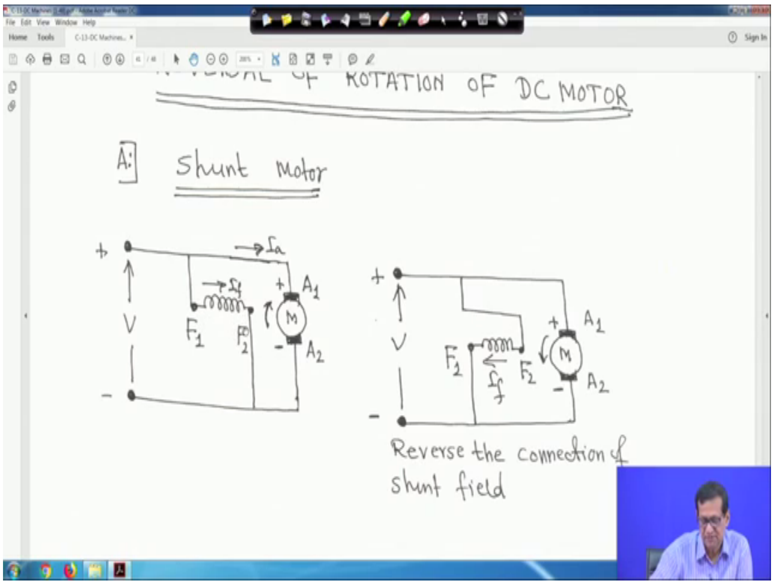

So, next is the reversal of rotation of DC motor or shunt motor.

Suppose this is the connection of the shunt motor F 1, F 2 is the field terminal, A 1 A 2 armature terminal right. So, if you want to if you want to here also.; it It is shown your what you call F 1 F 1 F 2 and this thing now, if you want to interchange the I mean, if you interchange the field terminal then, if you see this diagram F 1 F 2 connected, but now this point is connected here and this point is connected here this is; that means, your direction or this is the earlier, it was your what you call current was flowing in the field from F 1 to F 2, this connection is flowing F 2 to F 1 and torque is proportional to your product of the your, we have seen that product of your phi into I a right.

And phi is proportional to your field current right. So, in that case what will happen as your, that your field winding current is reversed. So, machine will rotate in the opposite direction here, it is shown the in the clockwise direction. So here, it will rotate in the opposite direction, if you reverse the your only field correction right field winding correction.

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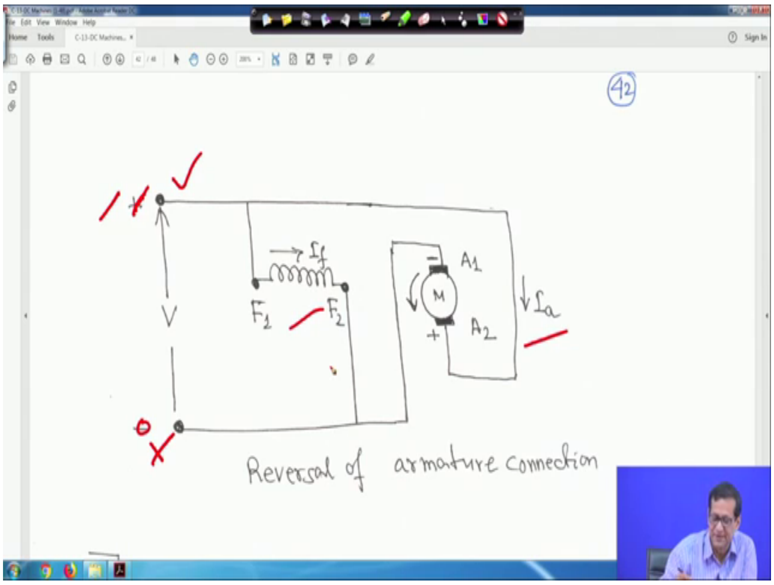

Now, now if you interchange, now the keep the field as it is F 1 F 2, now interchange the armature connection right; that means, plus terminal here I have brought to A 2 and minus 1 I have brought to A 1 I mean here, just we have interchanged these 2, these 2 connection A 1 A 2 reversed in that case your, what you call direction of the armature current is changed, but field current direction remain same. So, machine will rotate in the opposite direction right.

So, your that is either; that means, either you interchange the field connection or you interchange the armature connection such that machine will rotate in the reverse direction, but if you interchange both F 1 F 2 and A 1 A 2 both machine will rotate in the same direction because, torque is proportional to the what you call your phi into I a right product of these 2 right. So in that case, phi proportional to I f;. ~~So~~so, both I f and armature current direction is changed. So, machine will rotate in the same direction right.

~~So,.~~ So, in; that means, if you either of this if you interchange machine will rotate in opposite direction, but if you change both then machine will rotate your, what you call in the opposite direction as you saw, if you both you change then machine will rotate in the same direction and another thing is the terminal voltage, if this terminal voltage suppose, this is plus, this is minus, if you interchange this terminal suppose, if I connected to minus and if I connected to plus machine will rotate in the same direction right in your laboratory, you can verify easily right.

Because, if you interchange also both the field current and your current armature current both direction will change;. Soso, ultimately torque is proportional to your phi into I a both your phi into I a; that means, in generally torque is proportional to product of field current and the armature current. So, both directions are changing. So, machine will rotate in the, what you call in the same direction. So, if you interchange this polarity also it will rotate in the same direction, if you interchange both filed or both field and armature, it will rotate in the same direction, but either field or armature, if you interchange then it will rotate in the reverse direction right. So, this is very simple thing.

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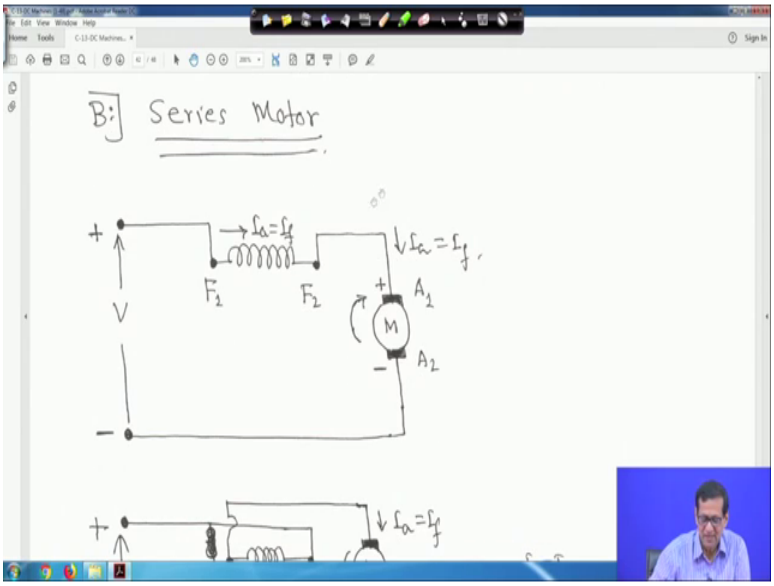

So, now for series motor here also F 1 F 2 is there A 1 A 2 is there and I a is equal to field current for series motor also if you inter[change]- reverse the direction of this one, this point is connect to F 2 and this point 2 connected to F 1 then here field current or armature current through, the field winding that from F 1 to F 2 F 1 to F 2 right, if you reverse interchange, this it will move F 2 to F 1.

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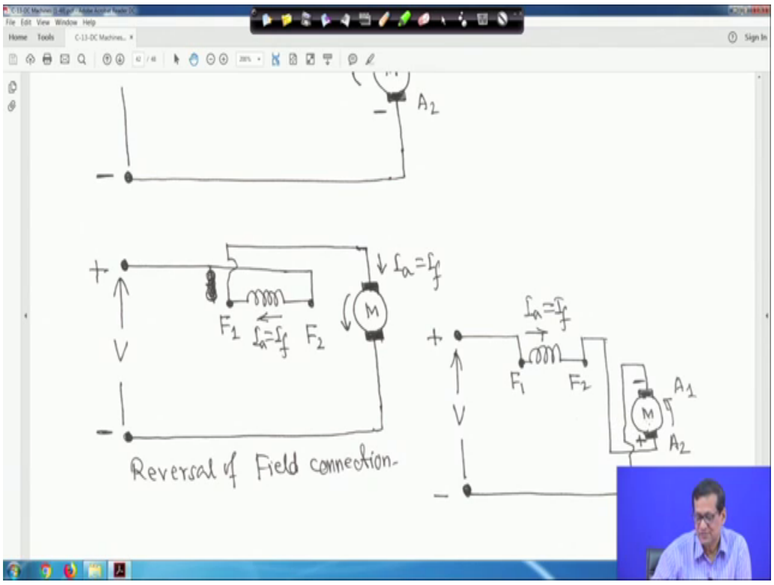

So, this way that your what you call direction of this can be changed here, it is showing your what you call clockwise here, direction is showing anticlockwise because, you are reversing the direction of the field current;. ~~Similarly~~similarly, if you reverse the direction of the armature current also in this case. So, the here also, if you when you are reversing then in this case also machine will rotate in the reverse direction, but if you make both then, it will rotate in the same direction, if you interchange the polarity of this supply line also machine will rotate in the same direction right.

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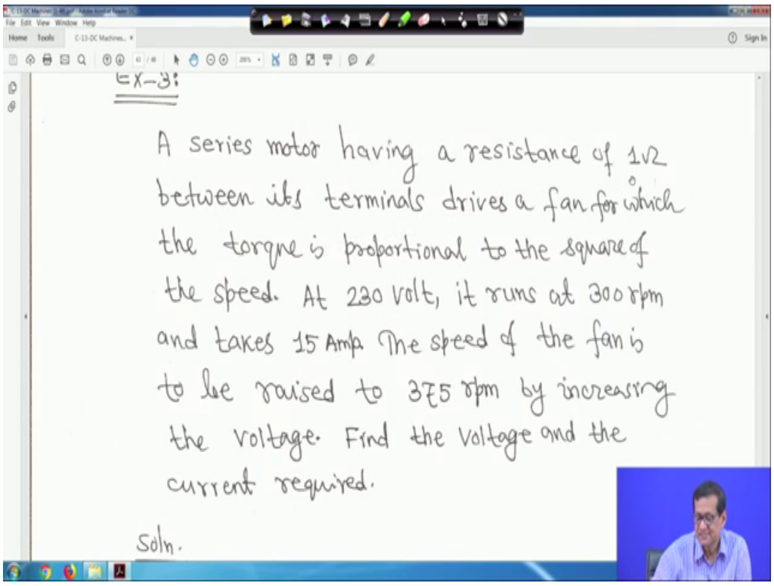

Next is an example. So, a series motor having a resistance of 1 Ohm between it is terminal drives a fan for which the torque actually is proportional to the square of the speed; that means, T proportional to n square right at 230 volt, it runs at 300 rpm and takes 15 ampere, the speed of the fan is to be raised to 375 rpm sorry, by increasing the voltage, find the voltage and the current required, this is the problem right. So, at 32 volt it runs at 300 rpm and takes 15 ampere, the speed of the fan is to be raised to 375 rpm by increasing the voltage, find the voltage and the current required right.

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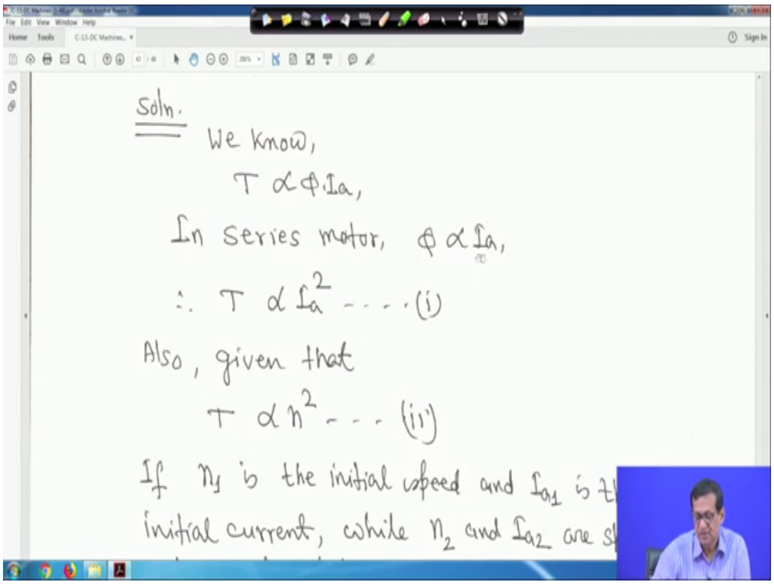

So, we know that torque actually proportional to phi into I a. Now the in series motor phi is proportional to I a; that means, if phi proportional to I a; that means, torque proportional to armature current square.

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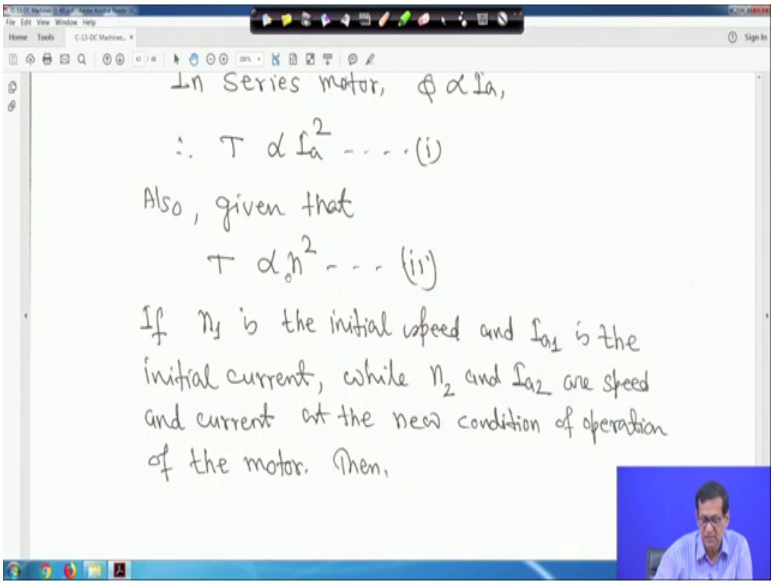

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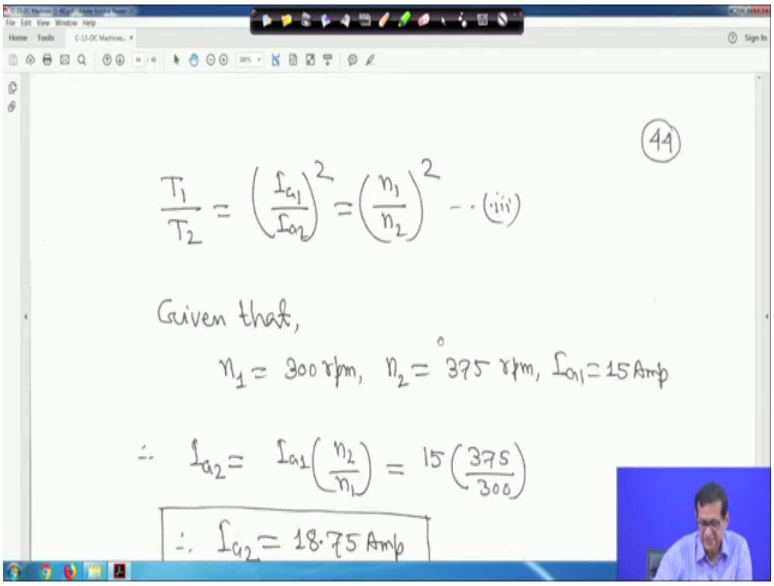

Now, also given that torque is proportional to n 1 square, if n 1 is the initial speed and I a 1 is the initial current, while n 2 and I a 2 at speed and current at the new condition of operation of the motor then, we can write because, it is T proportional to n square. So, first case if it is T 1 second case torque is T 2.

Say, then it will be T 1 upon T 2 is equal to I a1 upon I a 2 whole square because, torque is proportional to I a square right and it is given that torque is proportional to n square;

that means, T 1 by T 2 is equal to I a 1 by I a 2 whole square is equal to n 1 upon n 2 whole square, this is a equation 3 it is given.

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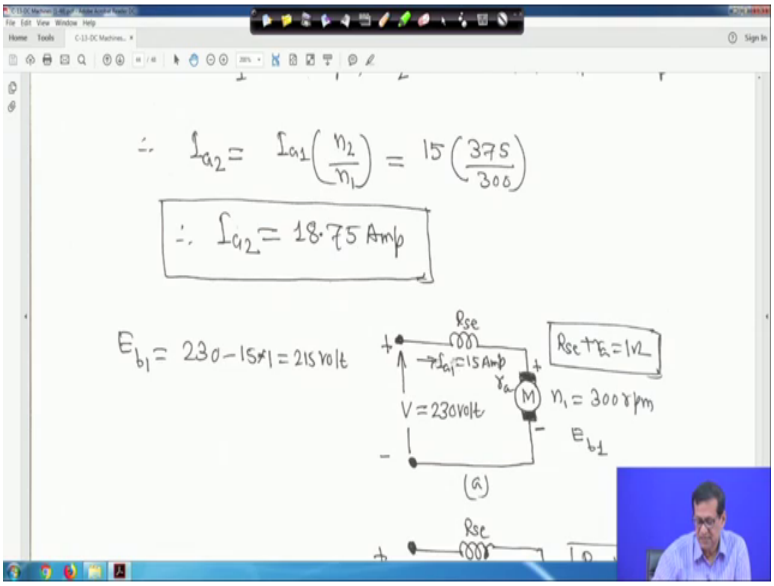

Now, it is given n 1 is equal 300 rpm, n 2 is equal to 375 rpm and I a 1 is equal to 15 ampere this is given from which, from these 2 equations from these 2 equations, you can find out I a 2 will be 18.75 ampere right therefore, the back Emf E b 1 will 230 minus first phase current was 15. So, 15 into 1;. Soso, 215 volt right and n 1 is 300 ampere and R s e plus r a, we assume 1 Ohm right total.

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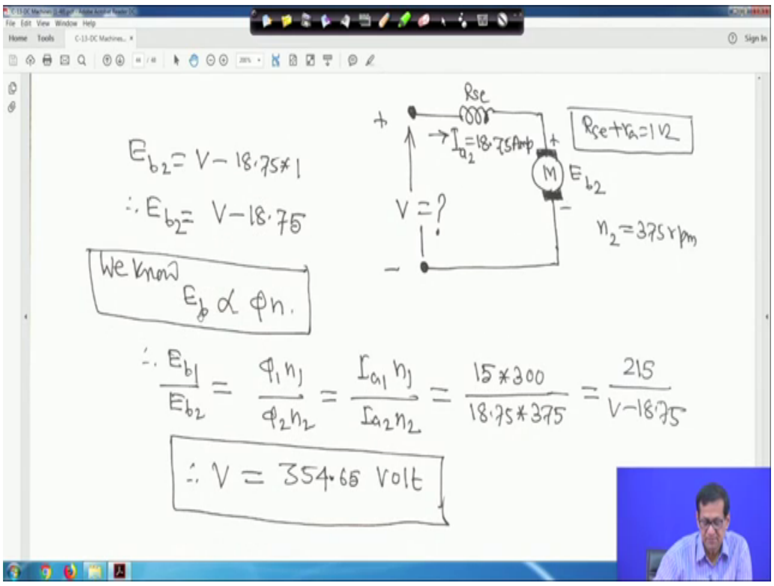

-And next is your in the second case, I a 2 is 18.75 ampere and R s e plus r a is 1 Ohm, it is given, this is R s e and this is n 2 is 375 rpm therefore, E b 2 is equal to V minus your, 18 70.75 into that r a plus R s e 1 that is. So, it you will get V minus 18.75, but V we have to determine and we know that back Emf proportional to flux into speed therefore, E b 1 upon E b 2, first condition and second con[dition] you can write phi 1 n 1 upon phi 2 n 2 right is equal to and because, it you can write I a 1 n 1 upon I a 2 n 2.

Because, your flux is proportional to the armature current in series machi[ne] series motor, there phi 1 by phi 2 is equal to basically, I a 1 upon I 2. So, substitute here, it will be I a 1 n 1 upon I a 2 n 2. So, substitute all this value because, all this values are known right. So, and this is E b 1 upon E b 2, E b 1 is 215 volt and E b 2 is this much V minus 18.75. So, this one is equal to this one. So, from which if you solve, you will get V is equal to 350.65 volt right.

Now, next is another example. So, this is the answer. So, simple problem just you have to keep your relationship in your fingertip. So, everything will be solved right.

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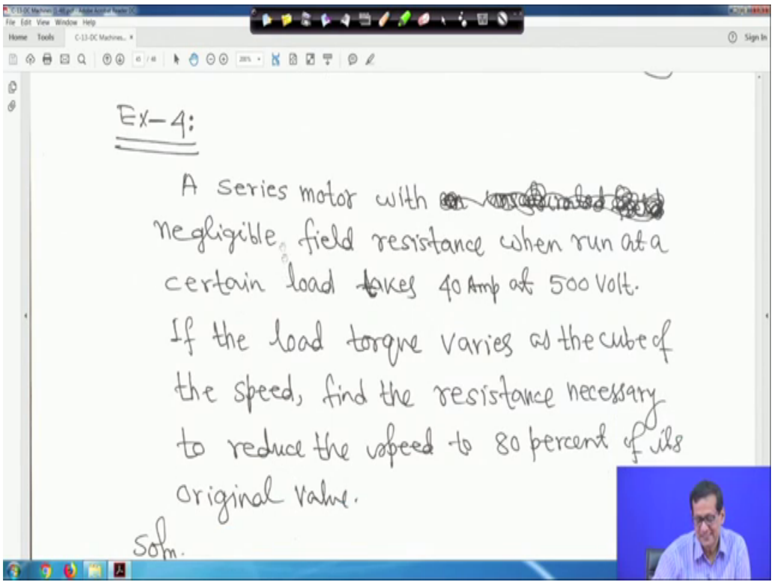

Now, next is a series motor with negligible field resistance, when run at a certain load takes 40 ampere at 500 volt, if the load torque varies as the [seues/cube] cube of the speed the torque is proportional to n cube, find the resistance necessary to reduce the speed to 80 percent of it is original value right.

So, if initially it was n, it will be it is it will be 0.8 n then right. So, you have to find out that your, what you call the resistance necessary right.

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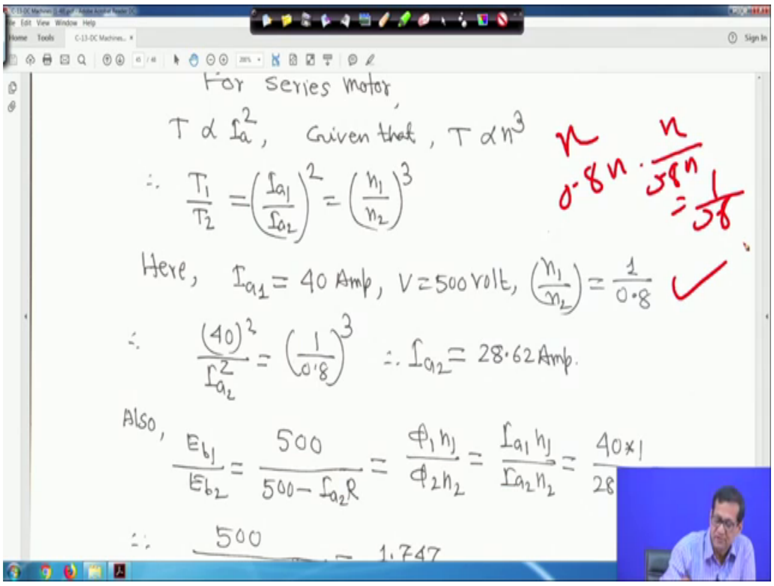

So, for series motor torque, we know proportional to armature current square and it is given T proportional to n cube; that means, we can write T 1 by T 2 is equal to I a 1 upon I a 2 whole square is equal to n 1 upon n 2 whole cube right first case, second case right.

Now, I a 1 is given 40 ampere, V is equal to 500 volt and n 1 by n 2 is given 80 percent. So, it will be your, what you call that second case, the speed is 80 percent of the first case because, we are reducing the speed. So, n 1 upon n 2 will be 1 upon 0.8, I mean I mean, it is ~~it is s~~ something like this, it is first case, if first case if it is n, first case if it is n then second case, it is 0.8 n therefore, n upon 0.8 n is equal to 1 upon 0.8 that ~~that~~ is written here right.

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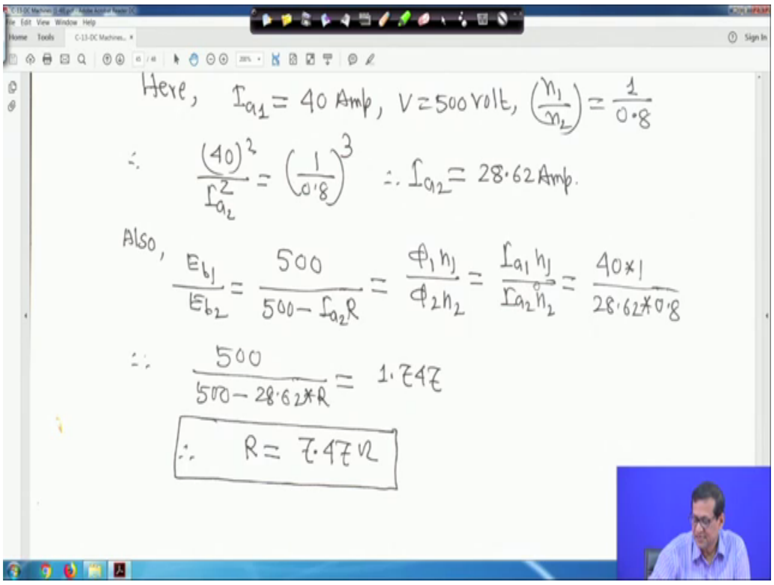

So, if; that means, these are the data given. So, 40 square upon I a 2 square is equal to 1 upon 0.8 cube from which, we get I a 2 is equal to 28.62 ampere right. Now also we know E b 1 is 500 volt. First case given, second case some resistance R is inserted. So, 500 minus I a 2 into r is equal to same as before 5 1 n 1 upon phi 2 n 2 is equal to I a 1 n 1 upon I a 2 n 2 same as before is equal to 40 into 1 right, I mean I a 1 is 40 I a 2 is 28.65;.- So so 40 upon 28.62 into n 1 upon n 2 actually, 1 upon 0.8 right. So, from which if you solve, you will get R is equal to 7.47 Ohm right. So, this is the answer, this much resistance has to be inserted right.

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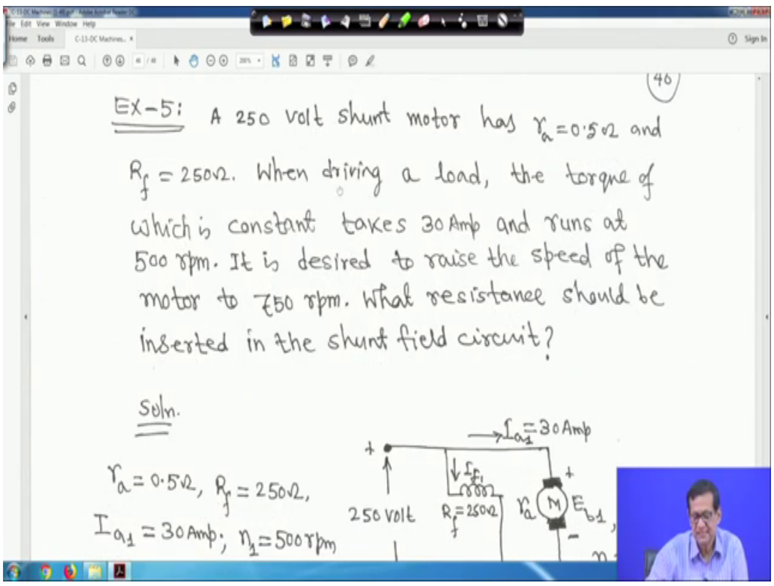

So, next is a 250 volt shunt motor has r a is equal to 0.5 Ohm and R f field resistance 250 Ohm, when driving a load the torque of which is constant takes torque is given constant takes 30 ampere and runs at 500 rpm, it is desired to raise the speed of the motor to 750 rpm. So, 500 to 750, you have to raise the speed, what resistance should be inserted in? The shunt field circuit right.

So initially, when this initially there was 1 resistance in the circuit. So, r a is 0.5, R f 2 50, I a 1 30 ampere, n 1 500 rpm right. So, everything is given. So, given that the torque of torque of the load is constant.

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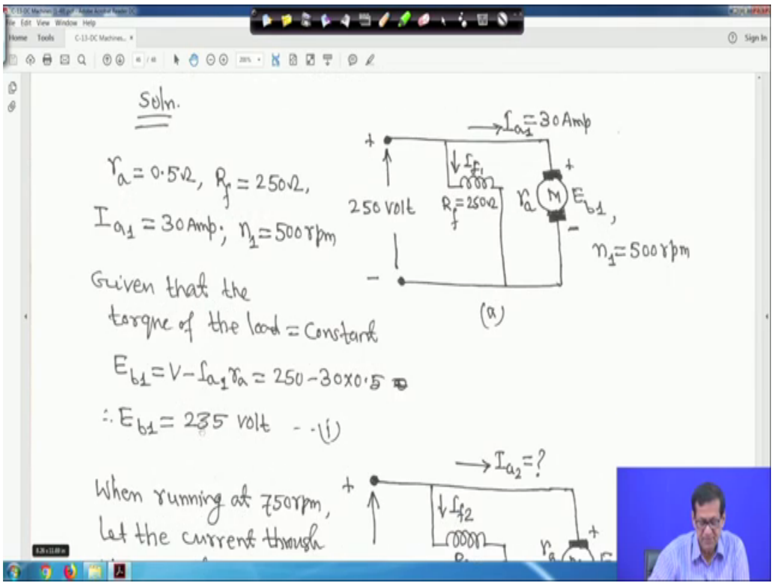

So, torque is a constant and back Emf in the first case E b 1 will be V minus I a 1 r a. So, V 250, I a 130 and r a 0.5;- Soso, 230 fie volt right in the first case.

Now, in the second case, we have to raise the speed to 750 rpm. So, a resistance R had been inserted here, we have to find out, what is the R? When running at 750 rpm, let the current through the armature be I a 2 at that time it is I a 2 right so; that means, E b 2 is equal to V minus I a 2 into r a.

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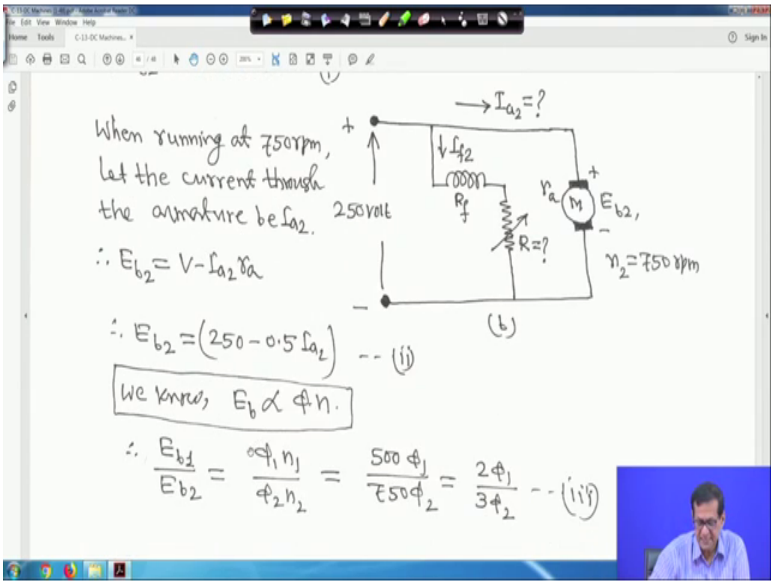

So, r a is 0.5 Ohm therefore, E b 2 is equal to 250 minus 0.5, I a 2 right, this is the circuit diagram for the second case.

-Now, we know that back Emf is proportional to phi into n or is same as before, we can write E b 1 upon E b 2 is equal to phi 1 n 1 upon phi 2 n 2 right. So, if you if an n 1 is 500 rpm first case and n 2 is the 750. So, 500 upon 750 into phi 1 by phi 2 that is 2 phi 1 upon 3 phi 2, this is equation 3 right.

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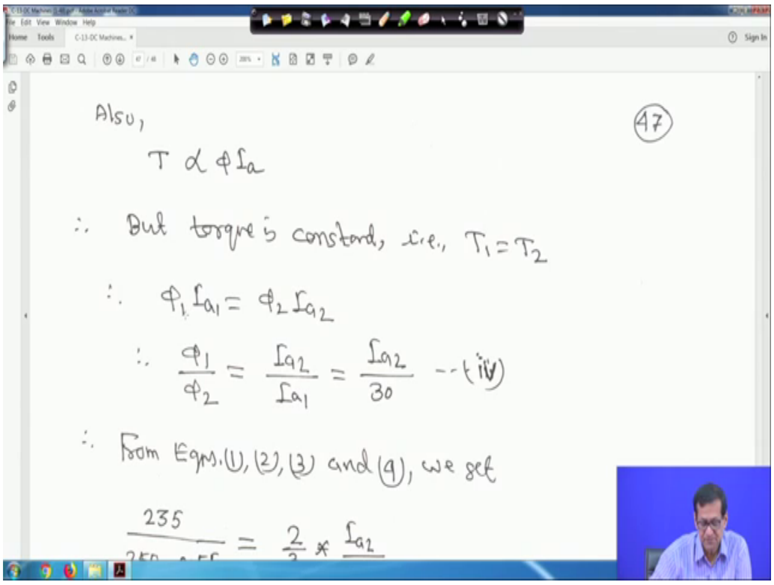

Now, torque is given that proportional to phi into I a, but torque remain constant, but torque both the cases torque remain constant. So, T 1 is equal to T 2; that means, for; that means, phi 1 into I 1 I a 1 is equal to phi 2 into I a 2 because, torque, this torque remain constant therefore, first case if it is phi 1 I a 1 second case, it is phi 2 I a 2 from which, we get phi 1 upon phi 2 is equal to I a 2 upon I 1 is equal to I a 2 upon 30 because, I a 1 is equal to 30 ampere right.

Therefore, from equation 1, 2, 3, 4 right.

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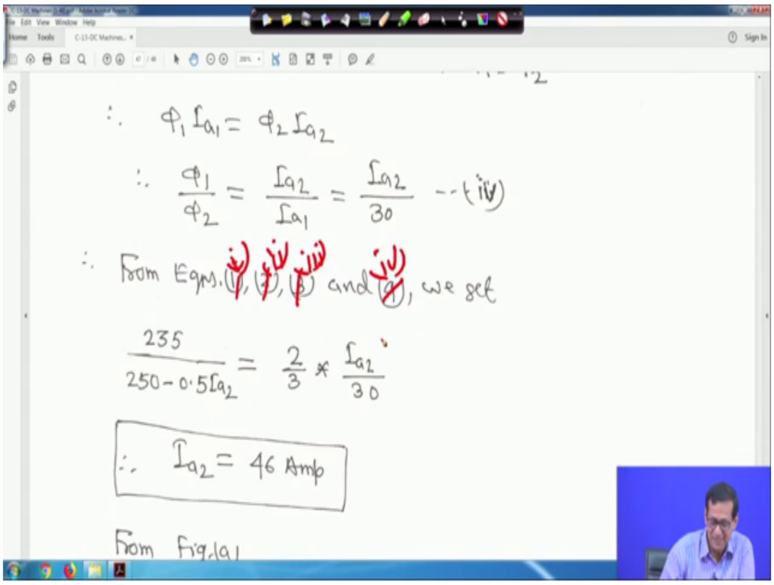

Therefore, from equation 1, 2, 3, 4 right So, actually this is your, what you call, this one will be italic right, this one actually, it is actually equation 1. This is your equation 2, this is equation 3 and this is equation 4 actually, this way some correction right. So, if you from equation 1, 2 and 3, 4 you substitute all these things. So, you will get, you will get your what you call that your 235 upon 250 minus 0.5, I a I a 2 is equal to 2 third into I a 2 by 30. So, if you solve this quadratic equation, 1 solution may not be feasible and answer will be I a 2 is equal to 46 ampere right. So, little bit practice is necessary.

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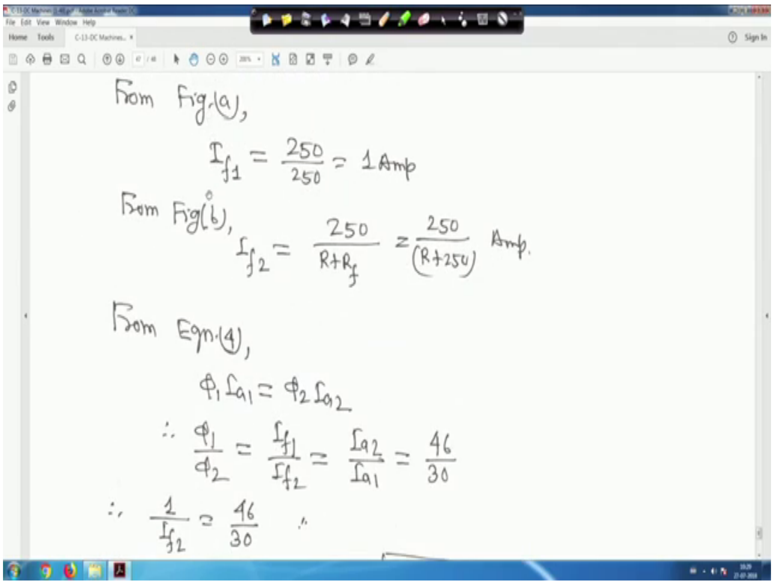

So, now from figure a;. Soso, as you as from figure a, we get I f 1 is equal to 250 upon 51 ampere because, if you look into this figure, this is your 250 volt and this is 250. So, for first case, field current was 1 ampere 250 upon 250 and in the second case, circuit the figure a the field current I f 1 will be 250 upon 251 ampere, but second case, I f 2 will be 250 upon R plus f R f.

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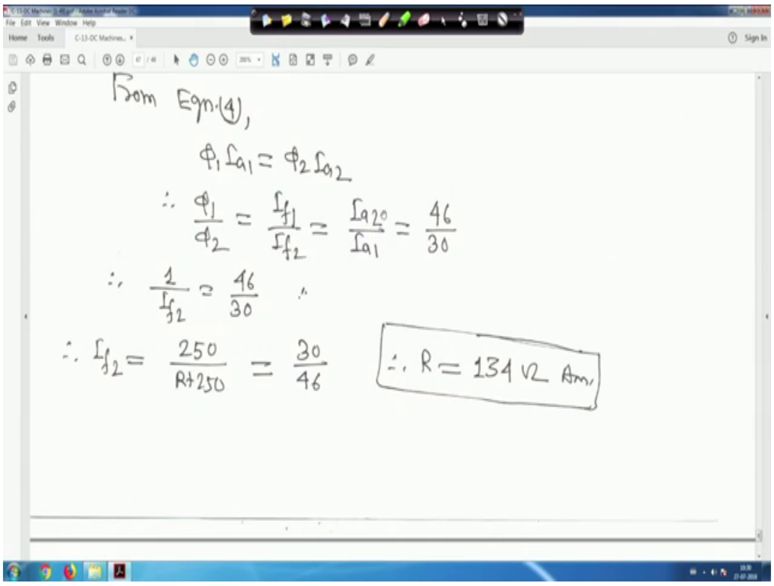

So, 250 upon R plus 250 ampere. Now, equation 4. So, phi 1 I a 1 is equal to phi 2 I a 2. So, we know that flux is proportional to the field current. So, we can make phi 1 upon phi 2 is equal to I f 1 upon I f 2 is equal to your, I a 2 upon I a 1, substitute I a 2 is 46, we got I a 1 30. So, 1 upon I f 2 is equal to 46 upon 30, but I f 2 is equal to 250 upon R plus 250 right. So, is equal to this 46 divided by 30. So, it will be 30 by 46. So, after solving this for R, you will get R is equal to 134 Ohm, this is your answer right.

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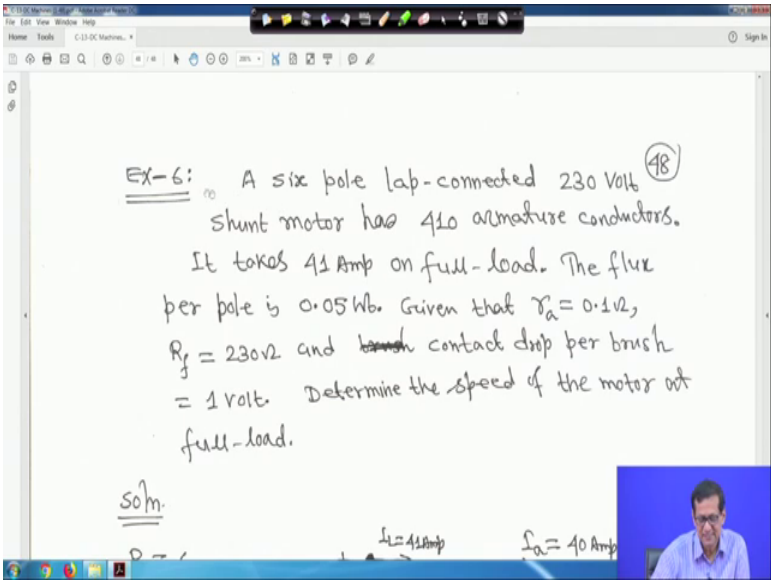

So, next is that example 6. A six pole lap connected 230 volt shun motor has 410 armature conductors, it takes 41 ampere on full load, the flux per pole is 0.05 weber given that r a is equal to 0.1 Ohm field resistance R f 32 Ohm and contact drop per brush is given 1 volt. So, 2 brushes will be there. So generally, it will be total will be 2 volt right, it is given per brush determine the speed of the motor at full load.

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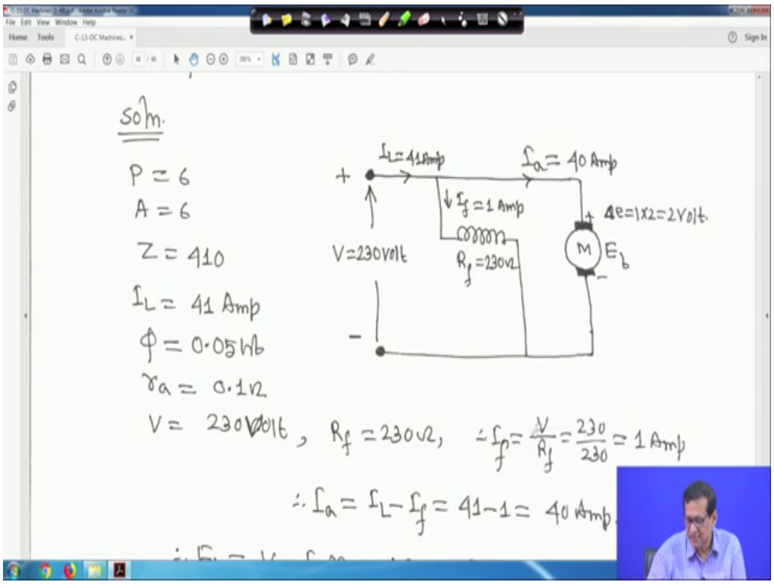

So, it is given lap connected pole is equal to 6. So, therefore, for lap connection parallel path will be A is equal to P is equal to 6 right. So, Z is equal to given 410, that number of conductor that this current I L is given 41 ampere, flux is given 0.05, weber r a armature resistance is given 0.1 Ohm, terminal voltage V is given 230 volt, R f is given 230 Ohm therefore, all this everything, you put here and there are 2 brushes. So, delta E will be 1 into 2~~. So~~so, 2 volt right. So, what will happen? First, you find the field current.

I f is equal to look at the cursor V upon R f that is 230 upon 230 is equal to 1 ampere right.

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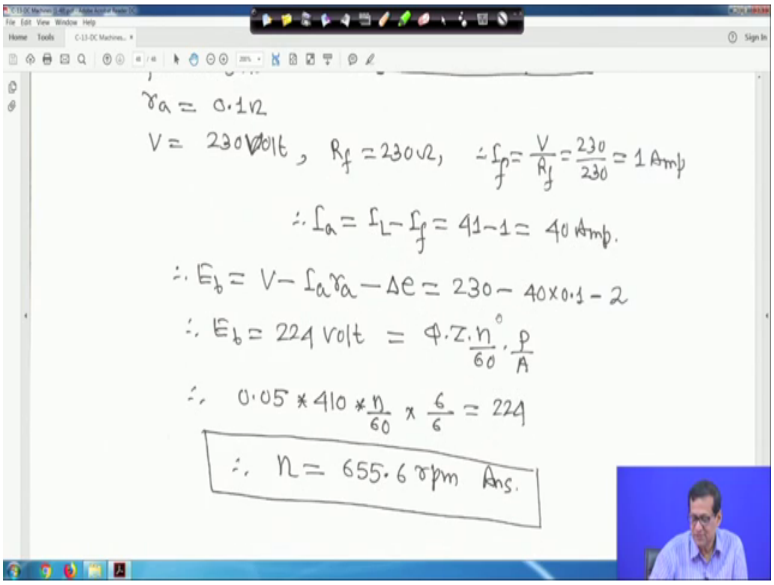

Now armature current, this I a at this point, you apply kcl. So, I a will be I L minus I f; so, 41 minus 1. So, 40 ampere, now in this case, the brush contact drop is given per brush 1 volt. So, E b you know V minus I a r a, but keep it in your mind also this drop has to be subtracted minus delta E, you may right such that, there should not be any small error.

So, but delta E will be 2 volt because, per brush 1 volt that is why, it is written 1 into 2. Look at the cursor, 1 into 2 volt right so; that means 230 minus 40 into 0.1 minus 2. So, now, we also know that E b is equal to 224 volt and we also know E b is equal to phi Z n by 60 into P by A. So, it will be phi is 0.05 weber Z is 410, n by 60, P is lap connection. So, A is equal to P. So, 6 by 6 is equal to 224.

Therefore n is equal to 655.6 rpm right. So, this is the answer. So, this problems are very simple problem, only you have to keep little bit in your mind with this course, I mean whatever little bit, we discussed this course will be is completed right. So, particularly at the first year level that is a single phase transformer has been covered right and induction machine and DC motor just, I have touched, I have not gone through the details considering that, you may be in the first year right or anybody can take this course, but it is just basic thing, we have discussed right not nothing is in detail.

And induction machine also because, most of the time, we have spent for deriving the equivalent circuit right, but starting of induction machine or starting of DC machine, we have not touched or many other things, we have not touched thinking that, you are just learning this. So, just those, who will be listening this last lecture right. So, my suggestion is the practice few problems, I mean take any book, I mean, you can take any good book and you just try right with this.

Thank you very much.