Electrical Machines - II
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Lecture – 08
Flux Density Distribution in Space and nature of emf

So, we were discussing about a single conductor motor and this was the configurations.

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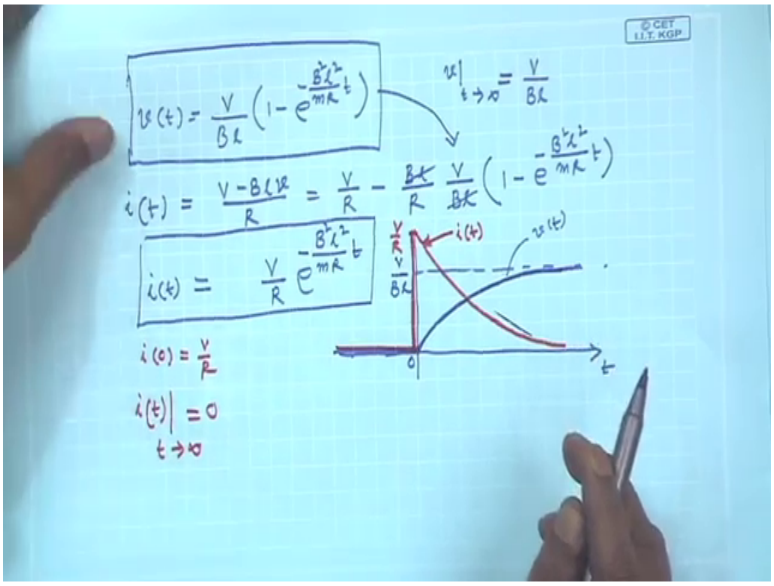

And in my last class we got the final expressions of current and velocity in this fashion. So, velocity essentially it will become 0. And not 0, final value of the velocity will be V by B l and final current in the circuit will be 0.

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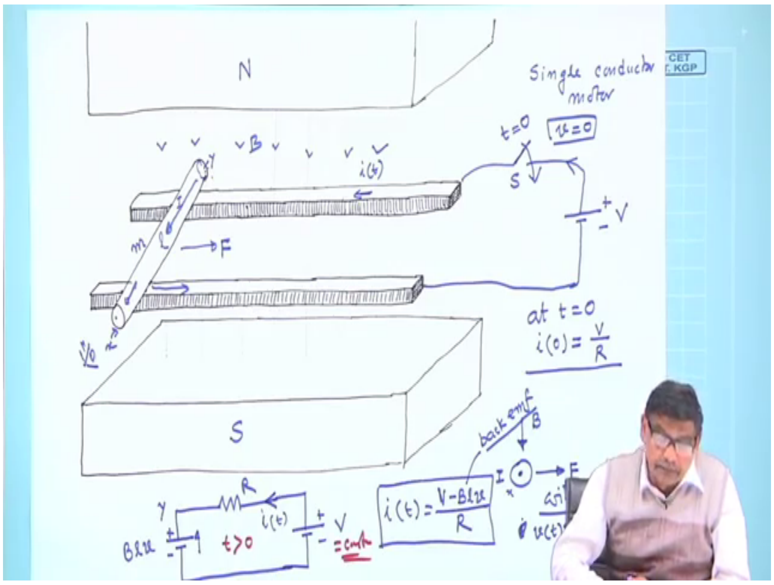

Now, let us see physically what is happening ok, you give switch on the supply it starts at accelerating. So, long this i t is present B i l is there. Therefore, it will go on accelerating velocity is increasing and as velocity increasing the back emf, here this fellow will also go up thereby current value will decrease. Now the question is after some time of course, should I have to wait for infinity to have this velocity? No it is like R l circuit charging, you can see the equation V by R sum 1 minus e to the power minus t by tau. It has got a time constant, depending upon this time constant maybe after 2 3 time constants only the velocity will be essentially constant and equal to capital V by B l where capital V is the supply voltage.

Now, when the velocity will become equal to capital V by l what will be this voltage?

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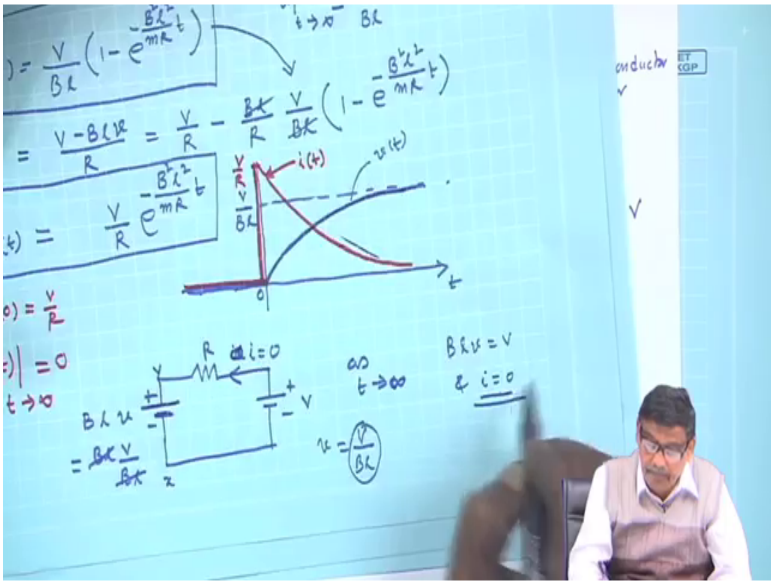

This circuit I recall. So, after sufficiently long time this voltage B l v as t tends to infinity this equivalent circuit how it will look like B l v, but velocity at t equal to infinity is capital V by B l. So, B l capital V by B l this cancels. So, the this back emf voltage across this x y of the conductor ends we will exactly be equal to capital v and the current in the circuit will be 0, under this condition. Current will be 0 therefore, there will be no force acting, force will also vanish B i l is the force. So, what the conductor is doing then after it attains a velocity whose value is equal to V by B l, what the conductor is going to do then? Conductor will move with this final velocity V by B l indefinitely because to move a thing at a constant velocity you do not require any force.

Therefore, it is consistent with Newton’s laws of motion because I have assumed there is no friction, nothing. Therefore, it goes it reaches a final velocity after that it will continue to move with that velocity therefore, velocity we will go on increasing. And the final velocity can be obtained when this B l v is equal to capital V and i is equal to 0. Of course, what is the power then, power it is not delivering any power to anywhere, but it will continue to move this circuit no current will be flowing.

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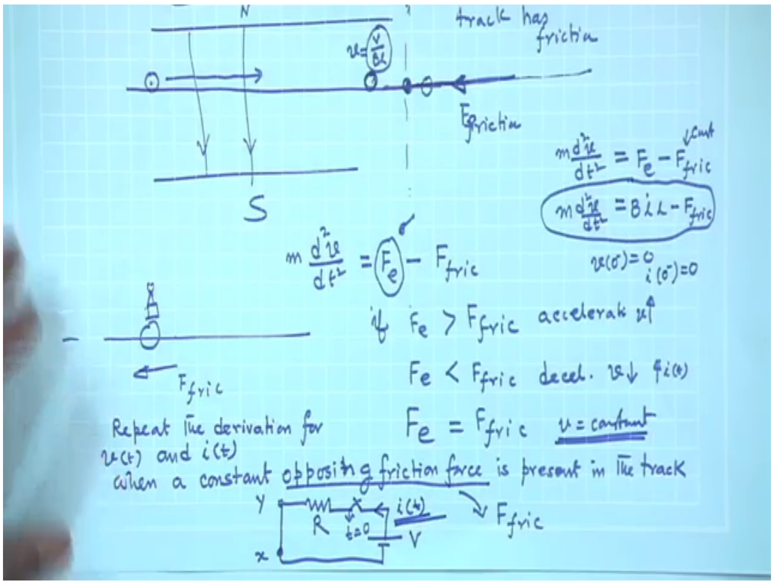

Now, I will tell you in this fashion that, suppose this is the track this is the conductor, I will draw this simple diagram, it and this side is North Pole above and this side is South Pole. So, lines of forces are like this all these things and it was accelerating you have closed some switch. Now you understand what I am talking about, it is moving then it reaches a final velocity V current is 0, after sufficiently long time. Now suppose in the track, in this zone after it has attained a constant velocity is equal to V by b l velocity. Now, after this there is a friction present on the track. Then physically what the conductor is going to do? It was moving with this final velocity capital V by B l to the right, suppose this portion of the track this track has friction which is in the opposite direction, this track no friction. So, that is how it has its velocity has developed, but when it enters this zone of the track.

Suppose there is some F friction, the moment it enters it let us argue like this. Till now the electromagnetic force was 0, here it was 0 because there was no i. Now the moment it enters here the dynamics of motion will be m d 2 v d t 2, this should be then minus F friction right here, why because there is no electromagnetic top present. Therefore, the moment it encounters an opposing force what this conductor is going to do? It will try to decelerate and velocity cannot change instantaneously. Therefore, the moment it enters here if you say a new t equal to 0 here at t equal to 0 plus velocity still is V by B l, but friction is acting in the opposite direction its velocity will then start decreasing.

So, at t equal to 0 plus and t greater than 0 it is acted on by an opposing for sure, therefore d 2 will decelerate, but the moment it decelerates is velocity decreases from capital V by B l to some lower value this current appears. That is the most important thing; opposing force velocity will decrease a bit. The moment it does so current once again inflows into the system, because B l v will become less than capital V supply voltage, and if it does then there will be an electromagnetic torque appearing. So, velocity decreasing electromagnetic torque appears.

So, long this electromagnetic term F e is greater than F friction, it will accelerate and if F e greater than F friction two forces now will, start acting acceleration mean v will increase if F e is less than F friction deceleration v will decrease. And if F e is equal to a friction then v is constant understood. Therefore, in presence of a constant opposing force finally, the conductor will settle down to a velocity which is less than its capital V by B l values and it will pick up such a speed such that enough current flows now so as to make B i l is equal to F friction. You do not have to worry, machine will slow down it will invite more current F e develops, how long it will continue? Till F e becomes equal to F friction because current will increasing when F e less than F friction i is increasing, and it did this will go on till F e becomes equal to F friction and a new velocity with which the system will now run, which will be less than capital v by l.

Therefore, any opposing force come that is called the loading of the thing then really it is working as a motor and dissipating some power imagine that this is the conductor I mean rail over I have got some seat here, I was not sitting earlier there is friction present in the track. If I now somebody sits here then mg increases, opposing force will increase therefore, therefore, your this moving conductor will draw more power. How it will draw more power? It will further slow down so that enough current is drawn once again it will move at a constant velocity which will be lesser than capital V by B l and that is how things will go.

So, this example shows that I can make a single conductor machine, I will give you an exercise specifically telling that repeat this exercise, repeat the derivation sorry for velocity and i t when a constant opposing friction force is present in the track. So, your conductor was like this, x y it has got resistance, now I have a switch s and there is my battery, source voltage capital V, this is R and switch is closed at t equal to 0, but the track has a constant opposing friction force call it a F fric. So, only thing I will give you hints in that case and it was otherwise stationary for t less than 0. So, your equation of motion should be m d 2 v d t 2 is equal to net force acting is electromagnetic force minus F friction this is suppose constant and this is equal to your B i l minus F friction.

So, this differential equation we will get modified like this, you solve it and initial condition is v 0 minus was equal to 0, i 0 minus was equal to 0 it is resistive circuit. So, i 0 plus will be also 0, no i 0 plus will not be 0 the moment you close the switch the conductor has not yet to move the current in the circuit will be V by R and indicate the current in this way. So, this is your exercise you try to do it.

So, this is the thing, this exercise tells you how one can get or so called imagine a motor because after all you can see this motor in practice how can I make a motor or here I can get mechanical motion in this way. Then the whole track over which there will be a North Pole, South Pole it is not practical type motor. But it brings out several things; one is how energy conversion takes place from electrical to mechanical and so on, how current behaves, how this bar attains a constant velocity. Constant velocity will be attained only when the electromagnetic force that is B i l sort of force is counterbalanced by the opposing force, switch is mechanical in nature it may be F friction or if it is did this is suppose a carriage here. If you put some weight on this carriage friction will also increase. Its velocity final steady state velocity will fall.

Therefore, the operations at steady state and during transient phenomena we have studied a, we have introduced in fact, that is suppose I say suddenly I change this battery voltage it was moving constantly under no load condition suddenly this v is may doubled. Then how once again this conductor will attain a new speed; I think you are getting the problems, very interesting problems suppose frictionless you have switched on the circuit it has attained a constant velocity.

Now, at that time what I do? After it has attained a constant velocity I will double this voltage supply voltage suddenly doubled, the moment you doubled it physically I can tell what is going to happen. The moment you double it speed cannot change instantaneously, before that instant when you are doubling this voltage velocity attained a constant value such that B l v and capital V exactly matched there was no current, it was moving nicely with constant velocity.

Now the moment you increase this voltage to twice its value velocity cannot change instantaneously. So, its voltage was earlier capital V type therefore, there will be suddenly there will be a current now, capital 2 V at t equal to 0 plus current will be 2 v minus V by R. And if this happens electromagnetic force will now appear it will further accelerate from its initial final velocity and where it will finally, settle down?

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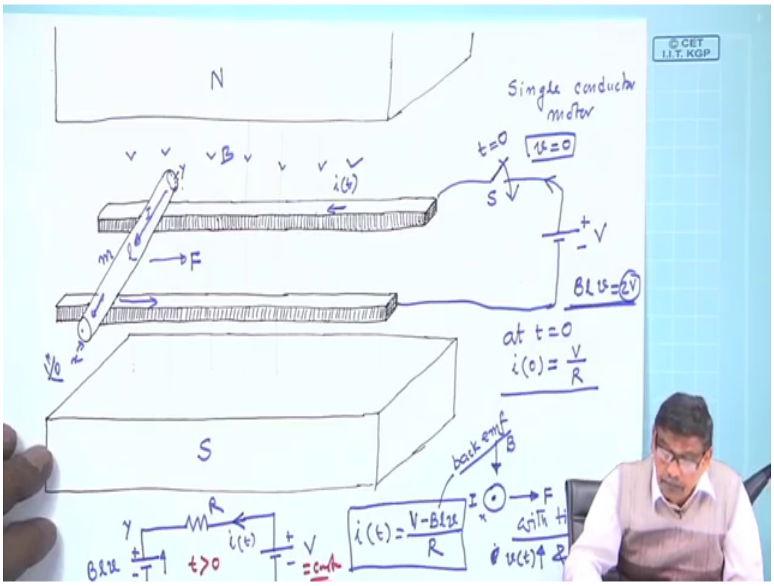

Once again it will settle down to such a voltage such a velocity where B l v will be equal to 2 v. So, it will run under no load condition, I mean several interesting features you can have. But, as I told you similarly for generator we will include couple of examples in your tutorial sheet, you must solve those problems for better understanding ok.

Now, it is time after telling all these things as I told you this cannot be a practical machine, the rest of the time let me tell you like this I will henceforth indicate your.

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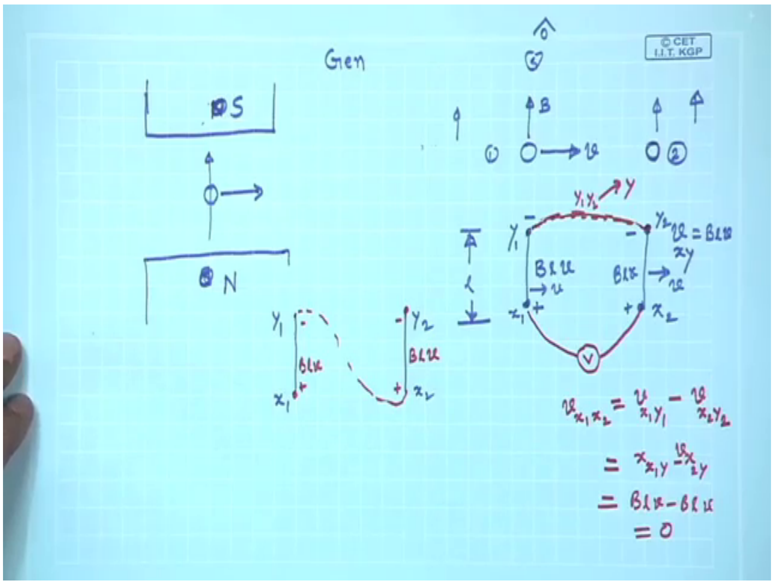

For example I can have a situation like this that here is a magnet say North Pole. And here is a magnet say South Pole and here is the conductor let us consider generator mode of operation and suppose it is moving like this, I will make it south and north like this. So, lines of force is this one. So, my simplified diagram will be like this, B arrow t is the one beyond which South Pole is present and backside is the North Pole those with this understanding I can avoid drawing this South and North Pole. So, this is B so, this site must be south lines of force always terminate on South of South Poles. So, suppose it is like this so, this is B and suppose this conductor is moving with a velocity v by some external agency is push pushing it or whatever it is.

Then I know there will be a voltage generated across the two ends and two ends of the conductor if you look from the top can be seen like this, x y. And, the polarity of the induced voltage by applying right hand rule this will become plus this will become minus. And the magnitude of the voltage is B l v where l is the length of the conductor is that v x y. So, potential of x with respect to y terminal is B l v [FL] and this B is present all along this space everywhere it is B like this.

Now, suppose this be it is doing like this I have another conductor. This, you listen carefully this is conductor 1 latest terminal b x 1 y 1, and there is another conductor 2 identical length which is sitting there of same length whose terminal is x 2 y 2 and it is also moving with velocity v. Therefore, the distance between these two conductors will remain constant if this is also velocity v, this is also velocity v it will remain constant. Therefore, this conductor why not it will also have an induced voltage of magnitude B l v and this side plus this side minus understood this scene. Therefore, these two conductors are moving in a uniform magnetic field B which is from bottom to top, arrowhead indicates this side the South Pole back side indicates North Pole whatever it is it goes like this.

So, there are now two conductors, x 1 y 1 and x 2 y 2 their two ends I have shown [FL] and these are moving. [FL] Suppose somebody take a piece of wire and join this two by a piece of wire, electrical connection he makes and then he tells that I will connect a voltmeter here. Everything is moving flexible wire see you imagine I want to see what is the potential between x 1 and x 2, what will be the answer? The voltage will be 0 because p x 1 x 2 is nothing, but potential of x 1 with respect to y 1 that is what B l v minus potential of v x 2 with respect to y 2 and this y 1 and y 2 are at the same potential because of this connection, therefore this will be. So, this y 1 y 2 let me call it y now a common point. So, this is v x 1 y minus v x 2 y and this will be B l v minus B l v and that is equal to 0.

Perhaps if I would have joined this to x 1 y 1 and this is x 2 y 2 suppose that flexible wire and this voltage is B l v plus minus, this is also B l v plus minus. So, if I could connect a took a piece of wire and connect this end then the voltage between x 1 and y 2 would have been doubled. That is B l v and this is also B l v with the polarity potential of x 1 with respect to y 2 will b v l v plus B l v ok. So, this you just keep in mind and tell me that if I have a single conductor, single conductor moving with a velocity v.

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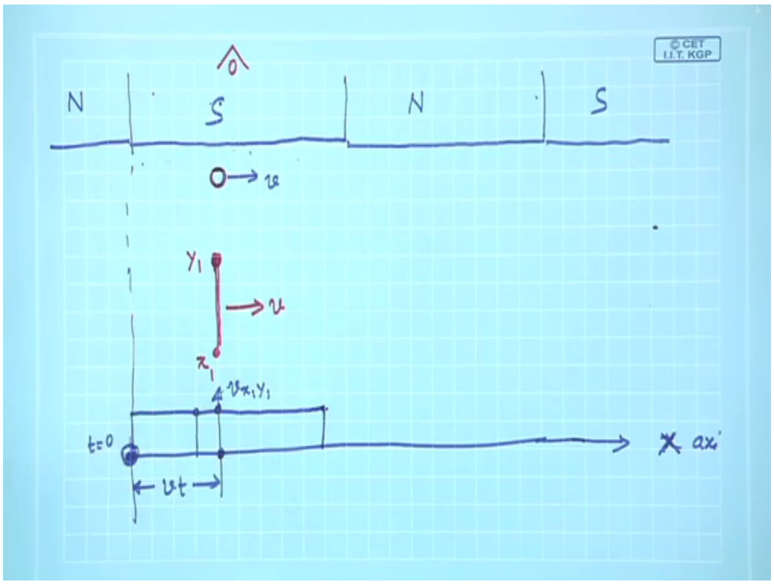

And I will now draw something up to this point suppose it is South Pole and then 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and suppose this point it is not and suppose it is repeating like that south earlier it was north. Suppose the magnets are arranged in such a way and a single conductor is moving and this conductor length you can see if you look from the top.

So, this is suppose x 1 and this is suppose y 1, this is the conductor and it is moving with a velocity v. Therefore, if I want to sketch this voltage v x 1 y 1 against the position of the conductor, suppose I start measuring the position this is position x x axis x suppose distance is measured from this. So, at t equal to 0 the conductor was here and then it is moving with a constant velocity v t and this is suppose any arbitrary position here so that this distance is v t.

I have started counting my time from here when the conductor was here some time as he left it has come here v t. Then what is the magnitude of the voltage B l v, and I want to sketch v x 1 y 1, it will be constant similarly it will be constant here. So, during this South Pole region total it will be like this, potential of x 1 y 1.

Anyway, I will continue this in the next class.

Thank you.