**Course Name: Design of Electric Motors**

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**Week: 01**

**Lecture: 04**

**Title: Magnetic Fields-2**

In this class, we will discuss about the force equations. Last class, we have seen about magnetic fields and Faraday's law, ampere's law and magnetic field sources, right. In this lecture, we will discuss about the force equation like Lorentz force law. So, if we place a current carrying conductor in a magnetic field, it will experience a force. Consider the north pole and south pole, other side south will be there and this side north will be there. Just keep it in mind and the flux lines will flow in this direction, north to south.

If we will place a current carrying conductor in this magnetic field, this is the current carrying conductor. If the current is coming out from the blackboard are coming out from the system, then this current carrying conductor also will produce the magnetic fields, right. It depends upon the attractions and repulsions of this magnetic field. This current carrying conductor will experience as a force.

Here, current is coming out, right. So, if we will see the magnetic field lines with respect to the north to south poles, it is in this direction and current is coming out with respect to the current polarity in the conductor. We will see the magnetic field lines in the anti-clockwise direction dot, right. It is in an anti-clockwise direction. So, the magnetic field repulsions, this conductor will be shifted upwards.

The force will be acting upward. The force equals to I cross B here. So, if we will reverse the current, so, if we are reversing the current, the magnetic field lines are in this B fields are in the same direction, but we are reversing the current. So, if we will reverse the current, the field lines direction will be changed clockwise direction. Now, then the conductor will move downwards.

Force will be in a downward direction. Here, force will be in upward direction because of the repulsions between the two magnetic sources. Here, the magnetic source one is nothing but poles, permanent magnetic poles and the second source is nothing but current carrying conductor. It depends upon the repulsions. We will see the force acting either upwards or downwards and exact force direction.

We will see with respect to the Flemings left hand rule also. After couple of minutes, we will discuss about Flemings left hand rule and right hand rule. Then how to find the force equation? So, this is the basic force equation with respect to the electrical field analysis. Force is equals to electrical force is equals to charge into electric field with respect to the monopoles. The same equation and same analysis if will adapt for the magnetic fields FB that is magnetic field force qB into B fields.

Is it fine? This equation is valid only when monopoles will exist, but the magnetic fields will not exist with respect to the monopoles. Only dipoles will be there and one more thing here with respect to the static charges. This equation is valid for static charges only and this equation should incorporate the moving charges where the charges are moving with the velocity v. Consider a charge q B which is moving with a velocity v. Then what is the force? Force will be directly proportional to the velocity as well as charge magnitude.

So, the final force equation with respect to the magnetic fields will be F equals to q B charge into velocity cross product with respect to the magnetic fields. So, here this equation is again sign sensitive. If charge is negative, then automatically force is reverse direction and if v is opposite, if charges are moving in a opposite direction, again force will be in a opposite direction. Similarly, if B fields are reversed opposite or reversed, then again force will be in a opposite direction. So, all three quantities are defining the force direction.

So, the total force is nothing but F equals to q E into electric fields with respect to the static charge plus q B into velocity cross product B. If the charge magnitude is same q into E bar plus v cross B. This is the final force equation with respect to the Lorentz force law. Now, we will see the force acting on a current carrying wire, complete wire how it will be looks like. Consider a wire carrying a current I and B fields are in this direction perpendicular to the current and the charges are moving with a velocity v and consider a charge at this particular point dq.

Now, force acting with respect to this particular charge is equals to dq is the charge and force equals to dq into v cross B. So, here dq equals to I into dt, the current flowing through the wire I equals to charge per second. So, dq equals to I*dt I am bringing here into v cross B. So, here dt into v that is dt is nothing but time and v is the velocity. Velocity into time is nothing but what distance.

So, this is nothing but d l I dot d l cross B bar. So, I l B into sin theta here theta is nothing but angle between v and B. So, the total force this is d f. So, the total force is nothing but we have to take the internal integration that is equals to integral I dot d l cross B bar.

This equation is the final equation for the force acting on a entire wire with respect to Lorentz force law.

Now, we will calculate the torque. Torque equation we will find. Torque is equals to force into distance between the two current carrying wires that is I am representing with x. So, force equation we know and x is the distance. Then the torque final equation is B I l x into sin theta.

Here theta is the angle between the B fields and velocity with charge velocity that is theta we can see here. This is the final torque equation. Torque is in Newton meter and force units are Newton. Next thing as of now we have find the cause for the force like current carrying conductor. If we will place them in a magnetic field there will be a force and the force magnitude we have calculated by utilizing the Lorentz force law.

Now, how to find the direction? For that we have to utilize the left hand thumb rule. Left hand thumb rule in thumb represents the force, fore finger represents the magnetic fields and middle finger represents the current. In order to find the force acting on a current carrying wire we can utilize the left hand thumb rule. All this force and B fields and current are perpendicular to each other all these three variables force, B fields and current. We will utilize the left hand thumb rule to find the force in electric motors and electromagnets in any other application of magnetic circuits.

Next as per the Faraday's second law if we will place the conductor in a variable magnetic field there will be a induced EMF across its terminals. If the coil is closed like if closed coil if you are placing in a magnetic field there will be a induced current. So, how to find the induced current direction? For that Fleming's right hand rule we have to utilize. In Fleming's right hand rule thumb represents the motion assume that in a magnetic field we are rotating the conductor or variable magnetic field is there we are placing the conductor in a variable magnetic field in either case. Fore finger represents the same B fields and middle finger represents the induced current.

So, in order to find the induced current with respect to the motion and magnetic fields we will utilize the right hand rule where we have to utilize this rule means in electric generators. With this I am concluding this lecture. In this lecture we have calculated the Lorentz force law equation and Fleming's left hand rule and right hand rule we have discussed. Thank you.