EXPLAINING FLEMING'S RIGHT AND LEFT HAND RULES

Abstract : Fleming's Right Hand Rule and Left Hand Rule for Motors can be explained in very simple way as just ' Relativistic Interaction of Moving Charged particles' which cannot explained by classical electrodynamics.

Introduction : This is continuation of my (Nabin Timalsina) paper " Explaining Magnetism by Relativity " and all mathematical treatment are included there[1]. This is an alternative explanation of Fleming's Right/Left hand Rules which are explained in that paper too.

According to classical electrodynamics ," there is no electric field near a long,straight-thin uniform current carrying conductor , so a charged particle moving parallel to the conductor experience no electrical force but experiences magnetic force."

But according to relativistic electrodynamics ," there is some electric field produced near such conductor due to length contraction and relativistic velocity addition , so a charged particle moving parallel to that conductor experiences some electric force which is equal to magnetic force explained by classical electrodynamics."

We got the following conclusions in that paper "Explaining Magnetism by Relativity" :

1. When a negative charge -q is moving parallel to direction of current then it experiences some repulsive relativistic electric force towards the wire . (by putting –q in place of +q in equation 2.3a)

2. When a negative charge -q is moving antiparallel to direction of current then it experiences some repulsive relativistic electric force towards the wire .(equation 2.9a)

3. When a negative charge –q is moving perpendicular to direction of current carrying straight conductor conductor then it experience negligible force in comparison to conditions 1 and 2 above .

Now we are going to explain Fleming's right and Left hand rules based on above facts.

Explanation of Fleming's Right Hand Rule

We are considering here a single circular loop of current carrying conductor as a magnet (we can also take a rectangular loop and make the explanation even better). The current is flowing in the circular loop of conductor in clockwise direction with drift velocity 'u' .

Let a vertical, straight conductor moves from left to right in front of the loop with velocity 'v' . Let M ,N ,O, X and Y be points on conductor as shown in figure below.

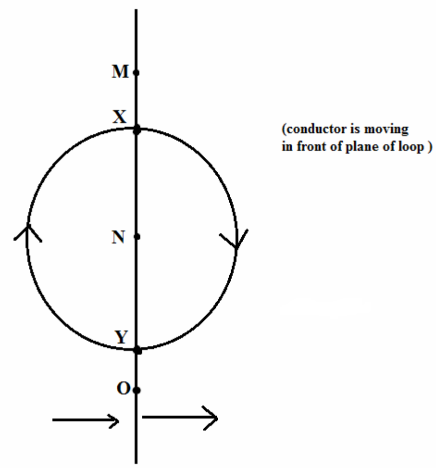

figure 1

Take only five points ; M ,N ,O ,X and Y of that vertical conductor as shown in figure below.

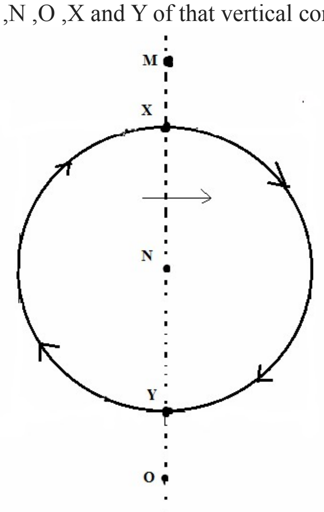

Figure 2

Divide the loop into two equal halves ; upper and lower half .

Each part of upper half of loop has current with some of directional component parallel to direction of electrons at N. These components repel the electrons . The electrons experience force downward away from the plane of the loop. The force has two components ; downward (vertical) and away from the plane of loop (horizontal).

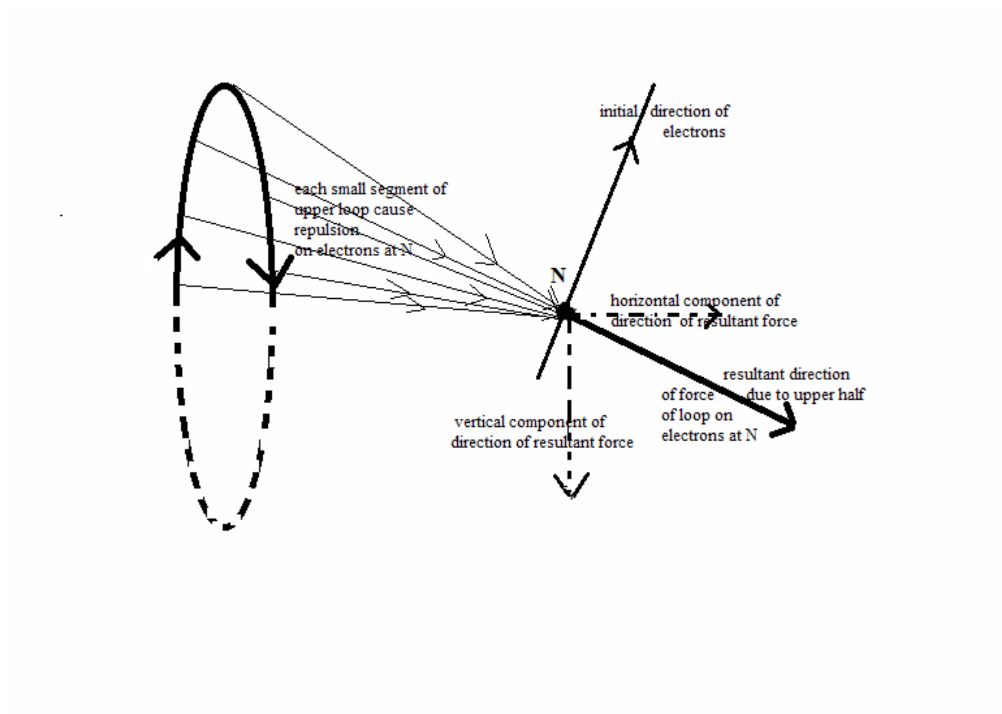

Figure 3

Each part of lower half of loop has current with some of directional component exactly opposite to direction of electrons at N . These components attract the electrons. The electrons experience force downwards towards the plane of loop . The force has two components ; downward (vertical) and towards the plane of loop (horizontal).

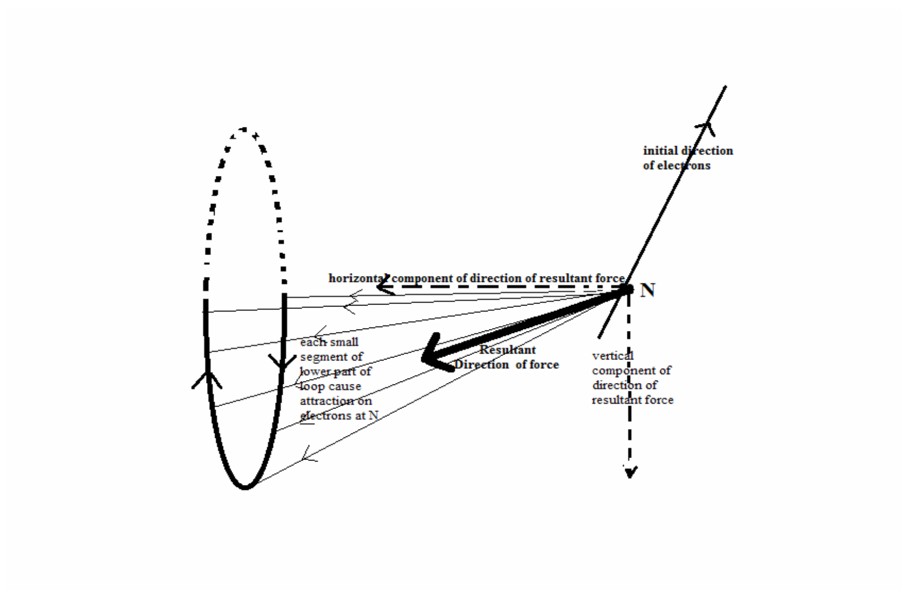

figure 4

The horizontal components of force on electrons (at N) due to these two halves of loops act on opposite directions and almost cancel each other.

But the vertical components of force on electrons (at N) due to these two halves of loops act on same direction and get added.

As a result , electrons at N experience a net force downward . The free electrons at N move/ try to move downwards in that conductor.

[* Note :There are some directional component of current vertical (both upward and downward) to direction of electrons at N too on both halves of loops but force on electrons due to vertical component of current is totally negligible.]

If we think about force on M (or points near M) on same way then we get that the electrons near M get repulsed upward because the repulsion of upward half of loop is more than attraction of lower half of loop(M is above the upper half). But due to downward movement of electrons below X, a partial positively ionized zone is created at that part of conductor. The positively ionized zone pulls the electron near M downwards which otherwise would go up due to repulsion.

Again, if we think about force on electrons near O then we find that electrons there try to move upward because the attraction of lower half of loop is more than repulsion of upper half of loop of current (O is below the lower half). But these electrons get repelled downward again due to the stream of electrons coming downward from the part of conductor above Y.

Thus electrons move downward in the wire . i.e. induced current moves upward.

In other hand, When a negative charge -q is moving parallel to direction of current then it experiences some repulsive relativistic electric force towards the wire .,positive charges in the conductor try to move exactly in opposite direction (i.e. upwards) but they are not motile . In such condition, the whole wire experiences some force upward till the wire is in motion.

We can consider a magnet as large number of such loops aligned parallel to each other . When a conductor moves near a magnet , all the loops of magnet affect the electrons of the conductor in the same way above .

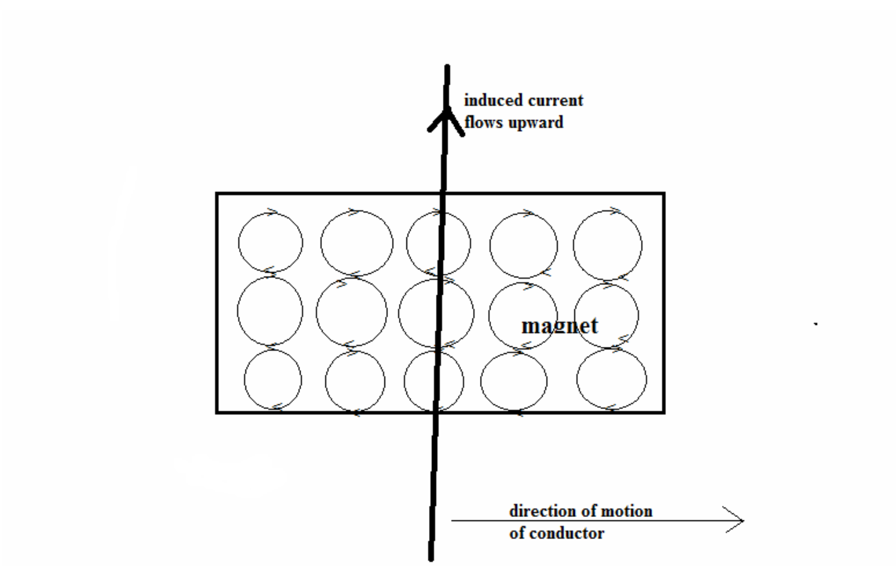

figure 5

As the left –right motion of electrons in the slowly get changed into downward vertical motion, the horizontal motion of the conductor gets decreased gradually. This is mechanism of Lenz's Law.

On comparing the above condition with Fleming's Right Hand Rule ,loops of current flowing in clockwise direction produce magnetic field lines going inside the plane of the loop. A conductor moving from left to right near the loop from the front should produce current flowing up(inside it) as shown in the figure :

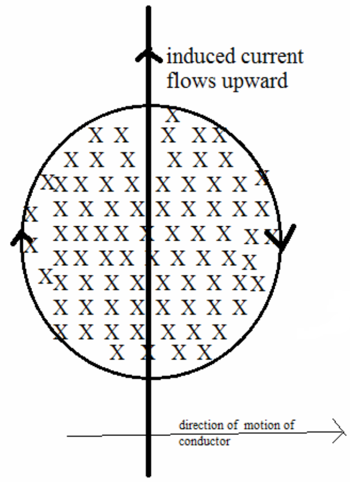

figure 6

('X' sign indicates that magnetic lines of force are going inside the plane of loop)

Thus our explanation of magnetic force as just ' a condition of Electric force with relativity applied' is able to explain Fleming's Right Hand Rule . We are able to show that the mechanism of Fleming's Right Hand Rule can be explained by ' relativistic interaction of charged particles'.

Explanation of Fleming's Left Hand Rule for Motors :

Consider an elementary electromagnet consisting of only one circular loop of current (we can also consider a rectangular loop for easier explanation but we generally consider a loop as circular one.) in which uniform current is flowing in clockwise direction.

A straight horizontal conductor is put in front of the loop in which uniform current is flowing from right to left. It means ,electrons are moving from left to right in this horizontal conductor.

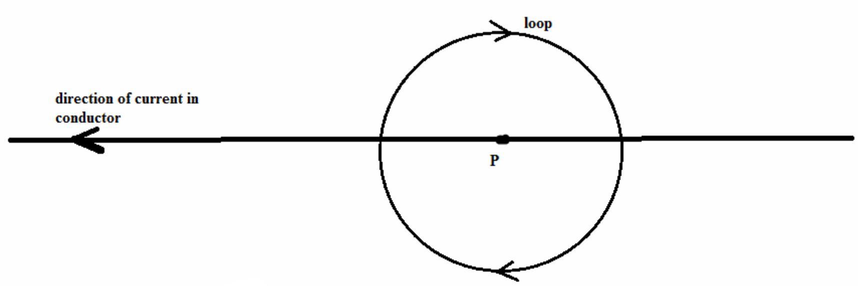

figure 7

Divide the loop into two equal halves ; upper and lower half in comparison to that straight conductor.

Take an electron at point P of that conductor . Since current in flowing from right to left in that conductor ,the electron at P moves from left to right as shown in figure below. Lets observe force on that electron due to those two halves of loop of current.

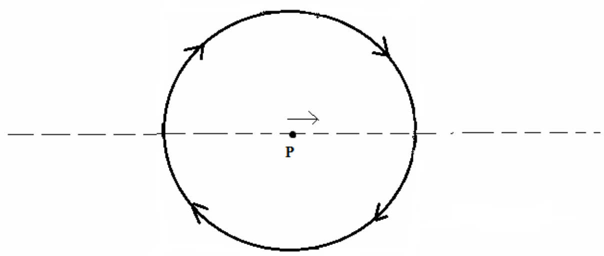

figure 8

The condition is exactly similar to that of figure 2 . By following the similar logics there we can come to conclusion that the electron at P experiences some force downwards.

Similarly, all other moving electrons in the straight conductor also experience force downwards. They push the whole conductor downward with some force . Hence as a result , the wire moves/ tend to move downward.

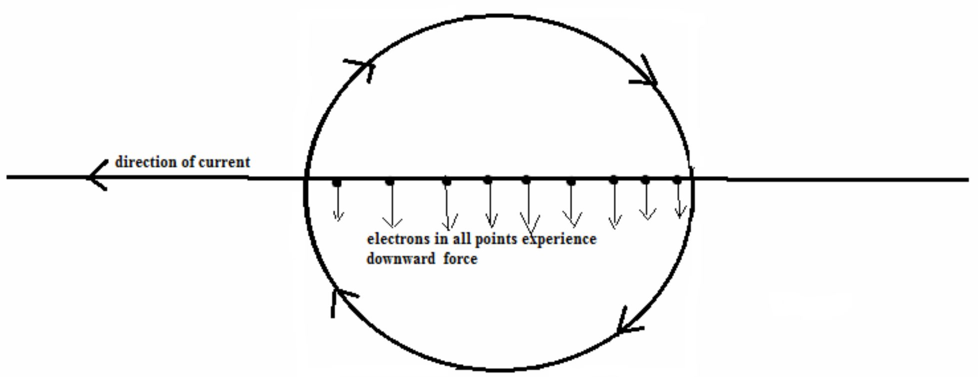

figure 9

If we study the figure 7 then after applying right hand rule we will find that the loop produces magnetic lines of forces that go inside the plane of loop (inside the loop) .When a straight horizontal conductor with current flowing from right to left is kept in such magnetic field then it experiences force according to Fleming's Left Hand Rule as shown in the figure below :

('X' sign indicates that magnetic lines of force are going inside the plane of loop)

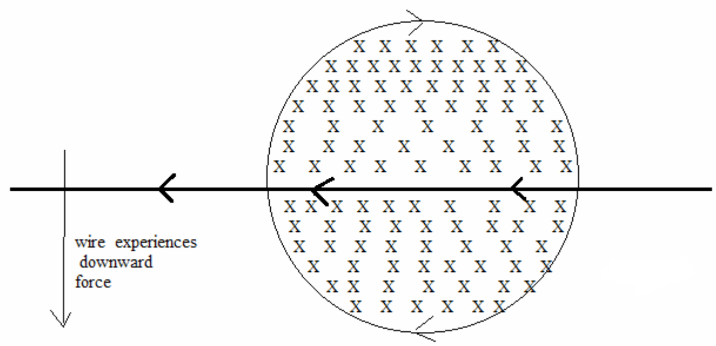

Figure 10

The result in figure 10 is exactly same as result in figure 9. Hence we can say that our model of 'Magnetism as relativistic interaction between moving charges' is totally successful to explain Fleming's Left Hand rule for motors too.

We can consider a permanent magnet as group of many such tiny loops arranged parallel. All the loops of current of the magnet affect a current carrying conductor in similar way discussed above .

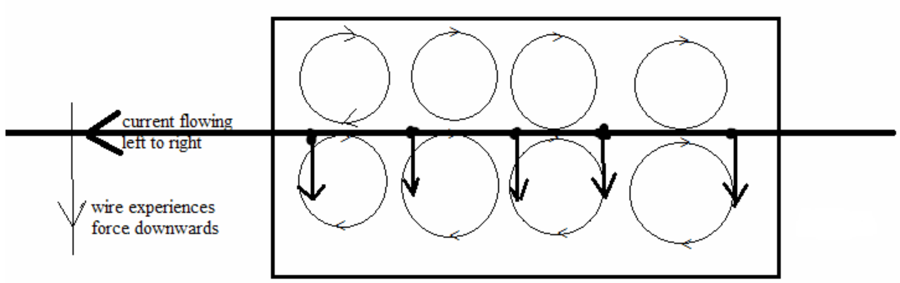

figure 11

CONCLUSION

Thus we are able to show Fleming's Right/Left hand rules as effects of ' Relativistic Interaction between charges ' rather as 'unknown causes' while studying electromagnetism.The mechanism of Fleming's hand rules are not mysterious at all .

Refernces :

1. http://vixra.org/abs/1904.0400