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What is magnetic field?

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Abstract:
On absence of magnetic monopoles in the universe, true nature of magnetic force and magnetic field is revealed. It is found that asymmetric nature of electric field is responsible to produce the asymmetric electric force on charged particles, consequently a charged particle follows a curved path. Therefore, it seems that the charged particle is acting under two forces, one is the effective electric force and the other is an apparent force which is always perpendicular to the velocity of the particle. The apparent force can be the true nature of magnetic force. In electromagnetic (EM) waves, the apparent force is proportional to the frequency of the EM waves. As the apparent force is the true nature of magnetic force, the magnetic force increases with frequency of EM waves. Further, it is found that there is phase different of 90 degrees in electric field wave and magnetic field wave in EM waves.

Keywords: *Electric field, Magnetic field, Magnetic monopoles, Asymmetric electric field, Asymmetric magnetic force, Apparent force, Field-field interactions, Phase difference*

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I. Introduction

Gravitational mass is responsible to produce gravitational field in space. Similarly electrical charges are responsible to produce electrical field in space. Thus the gravitational mass and the electrical charges work as sources for their own fields. In addition to these two fields there is another field working at the same level which is magnetic field. Unfortunately, its own source, thought as magnetic monopoles, are absent in the universe. In our surprise, in absence of its own source the field is created because of the motion of electrical charges. This is one of the mysterious facts observed in the universe. It was thought that if the magnetic field exists in the nature then its own source [1], which are magnetic monopoles, must be somewhere in the universe or they might have been created at the time of big bang. But no one could find it. Because of that, for a long period, magnetic monopoles have been a curiosity for physicists, and many of them strongly believe that they ought to exist. The detection of magnetic monopoles is still an open problem in experimental physics. Since a long period its discovery is awaited. But many efforts have been made to either create or to find their existence [2-7]. No one has succeeded yet. Therefore, such an endless discovery has forced to reanalyze the concept of magnetic field. The absence of magnetic monopoles and induction of magnetic field by motion of electrical charges may indicate that the real face of magnetic field can be different from that of assumed. It may be a one type of the electrical field but because of its improper appreciation may be appearing different from the usual one. With respect to that we have to investigate once again the magnetic field and magnetic force. Completion of this task may remove the magnetic field stuck to the electrical charges and provide an answer to absence of the magnetic monopoles in the universe.

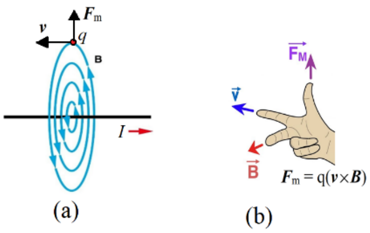


Fig. 1 Magnetic field of straight long conductor carrying current and magnetic force on a charged particle.

II. Revisiting the field of a current carrying conductor

It would be a simple approach to investigate what type of field is being produced by a straight long conductor carrying steady electric current. Field should be just like a pressure in the surrounding region of the substance. For electric current, it should be either in the direction of the current or opposite. Force applied by the field on any competent particle should be either in the direction of the field or in opposite. But according to the classical electrodynamics the field produced by a straight current is circular as shown in figure 1(a). Further the force is not in the direction of the field or opposite. It is perpendicular to both the direction of the field and velocity of the particle.

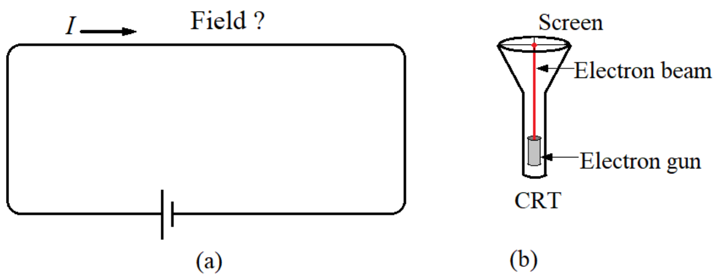


Fig. 2 Use of cathode ray tube (CRT) to determine field of current.

Conductor contains electric charges and no magnetic charges. Electric field around the conductor is null before carrying the electric current. Flow of steady electric current through the conductor causes to move only negative electric charges in one direction. Therefore, the electric field around the conductor cannot be null now. Electric field is simply a pressure around the conductor and can be experienced by placing electric charges in it. This field should apply force on the charged particle in one direction only. Aim is to find the structure of the field with using experimental arrangement as shown in figure 2. For that we use a cathode ray tube as shown in figure 3.

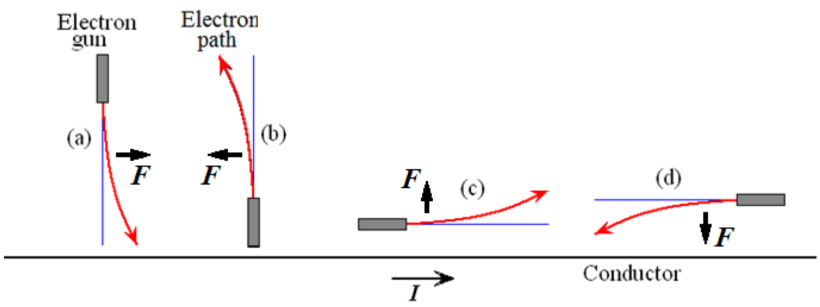


Fig. 3 Deflections in CRT in the field of a straight long current.

Deflections of electron beam near straight long conductor carrying steady electric current are shown in figure 3. At first glance it seems that the electron beam in different directions is experiencing forces in different directions which is unexpected. Force should be always in one direction. Therefore, we have to analyze one by one. Clearly, when we consider the case (a), the force ***F*** should decrease when we go away from the current as shown in figure 4. Further, if it is produced by electric field ***E*** then the field should be in opposite direction of the force as shown in figure 4. The force experienced by the electron should be asymmetric in nature and should be existed in terms of field-field interactions as explained below.

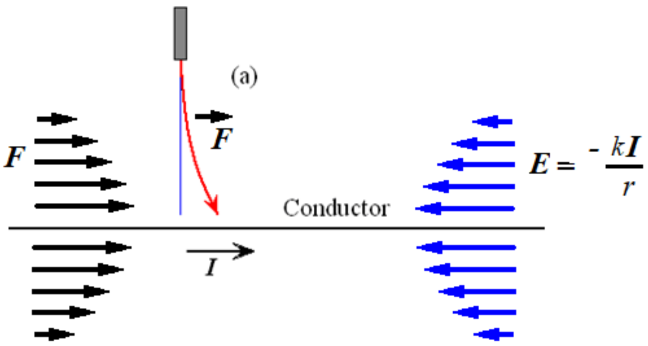


Fig. 4 Possible parallel electric field being produced by a straight long current.

2.1 Force through field-field interaction

Case (1): In fig. 5(a), the force between the two charges is expressed in terms of their charges. It may be considered as force in terms of charge-charge interaction.

Case (2): In fig 5(b), charge q_1 produces electric field $\boldsymbol{E}_1$ around itself. If another charge q_2 is brought into the field then the field applies force on the charge. It may be considered as force in terms of field-charge interaction. The force equation is given by $\boldsymbol{F}_2 = q_2 \boldsymbol{E}_1$, where $\boldsymbol{E}_1$ is the electric field produced by charge q_1 at position of charge q_2. Force is mutual. Therefore, charge q_2 also applies force on charge q_1 in terms of field-charge interaction by $\boldsymbol{F}_1 = q_1 \boldsymbol{E}_2$, where $\boldsymbol{E}_2$ is the electric field produced by the charge q_2 at position of charge q_1.

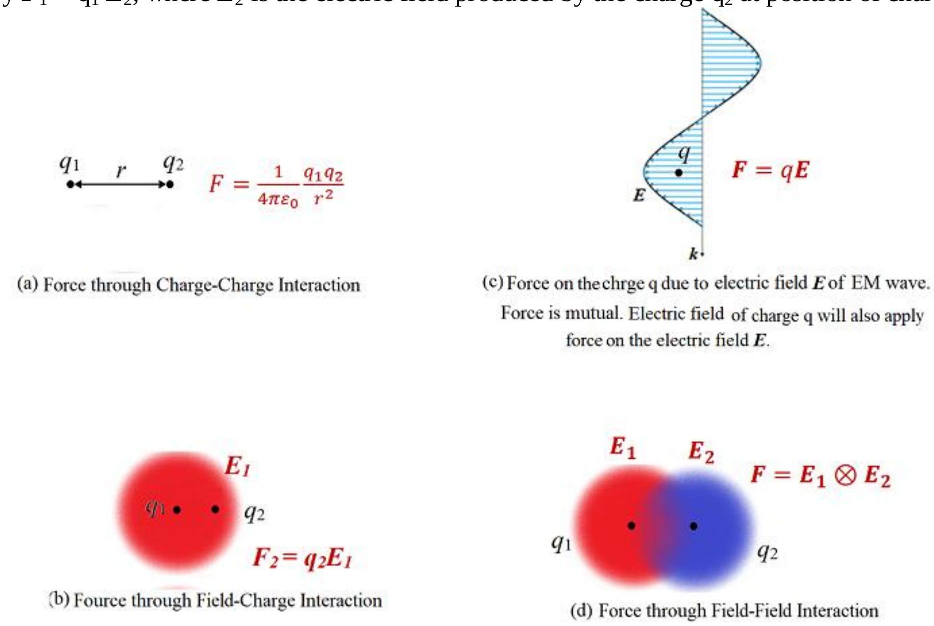


Fig. 5 (a) Force through charge-charge interaction. (b) Force through field-charge interaction. (c) Force is mutual. Charge will apply force on the electric field. (d) Force through field-field interaction.

Case (3): In fig. 5(c), an electric field wave in an electromagnetic wave is propagating with speed of light and interacts with a charge q at an instant. This field also applies force on the charge in terms of field-charge interaction. If $\boldsymbol{E}$ is the electric field of the electric wave at position of the charge *q* at any instant then the force equation is $\boldsymbol{F} = q\boldsymbol{E}$. But the force is mutual. Hence the charge *q* should also apply force on the electric field of the wave. As there is no charge associated with electric field of the wave, the electric field of the charge q must apply force on the electric field of the wave which may be considered as force through field-field interactions. Obviously, as the subjected charge *q* is always associated with its own electric field, therefore, the electric field of the applied wave must apply force on the field of the charge resulting into the force through field-field interactions. Thus finally one can conclude that the electric force exists not in terms of charge-charge interaction or field-charge interaction but it exists in terms of field-field interactions.

Case (4): In fig. 5(d), if two charges are brought close to each other, then force between them, either attractive or repulsive, is existed in terms of their field-field interactions. It means the electric field of first charge exerts force on the electric field of the second charge and vice versa. Thus a new electric force equation is to be developed which could explain the force in terms of the field-field interaction. At present we consider existence of electric force in terms of the field-field interactions for further discussion.

Using the concept of force through field-field interactions, let us once again explain the deflections in figure 3 with reconsidering in figure 6.

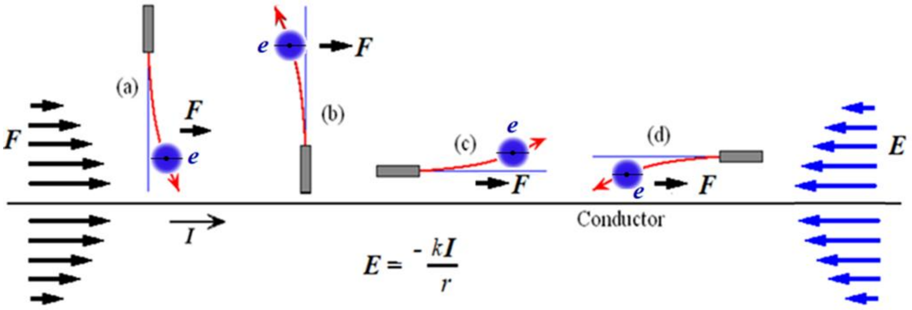


Fig. 6 Explanation of deflections of electron beam in different directions using force through field-field interaction in asymmetric electric field.

In case (a) of figure 6, the front field of the electron in the electron beam experiences greater force than the back field because of which it gets pushed along the direction of the force. In case (b), the back field of the electron experiences greater force than the front field because of which it gets pushed in the opposite direction of the force. In case (c), the lower field of the electron in the electron beam experiences greater force than the upper field while acceleration because of which it gets pushed into the weak field region. In case (d), the lower field of the electron experiences greater force than the upper field while deceleration because of which it gets pushed into the strong field region.

III. Electric Field of a Coil and a Bar Magnet

Electric field is parallel to the current and in opposite direction. Therefore a circular current carrying coil should a circular electric field as shown in figure 7(b).

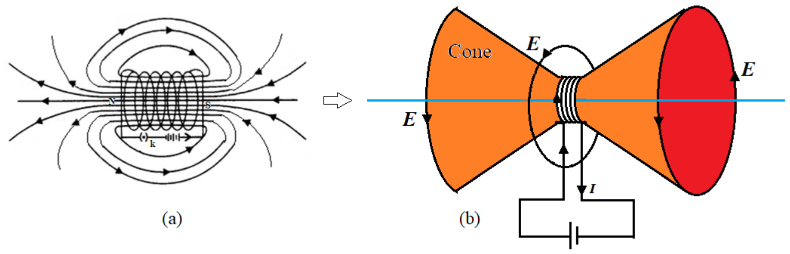


Fig. 7 Electric field of a current carrying coil having two electric field cones.

Electric field near the conductor of the coil is maximum. Therefore, cones of electric field are formed at both ends of the coil. Surface of the cone is formed where the magnetic field lines get turned. Electric field is maximum at the surface of the cone. Electric field decreases away from the coil.

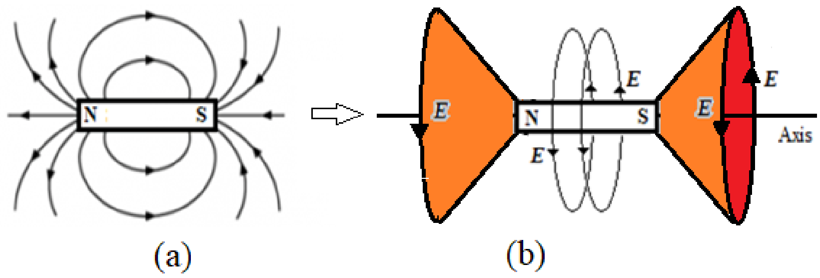


Fig. 8 Electric field of a bar magnet having two electric field cones.

In bar magnet, spin of unpaired electrons is aligned in such a way to produce non-zero effective current by them. This current is responsible to produce a circular electric field around the bar magnet as shown in figure 8(b). Obviously, this electric field is in opposite direction of the effective non-zero current. Two cones of electric field are formed at both said poles of the magnet. Electric field is maximum on surface of the cones and decreases away from the bar magnet in all directions.

Current produced in a superconductor supports to the circular electric fields produced by a current carrying coil and a bar magnet. The electric field of the coil tries to accelerate the charged particles in the direction of the field producing circular current in the superconductor because of which the superconductor gets pushed away from the coil in the weak field as shown in figure 9(a). Because of that we consider superconductor as a diamagnetic material.

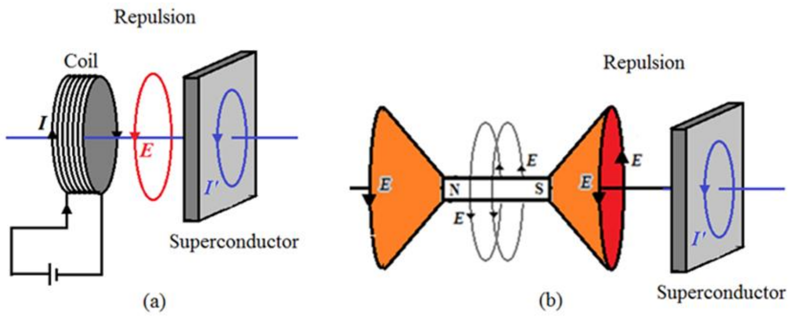


Fig. 9 Electric current produced in a superconductor due to (a) electric field of a coil and (b) electric field of a bar magnet.

Similarly the electric field produced by the current in the superconductor pushes the coil apart resulting into the repulsion between them because of which the superconductor is considered as diamagnetic material as shown in figure 9(b). Similar thing happen with bar magnet. Such current is not produced in ordinary conductors and is a part of investigation. If the applied electric field is alternating then produces alternating current in ordinary conductor and is governed by Faraday's law of electromagnetic induction. Though we know magnetic field and magnetic force, why we require the Faraday's law to tell e.m.f. produced in secondary circuit is really beyond our imagination.

IV. Verification of the Electric Field Cones Produced by Bar Magnet

As the electric field is maximum close to the current, therefore, electric field strength should be maximum near the wires forming circular cones at both ends of the coil. The electric field in the region of the cone should increase away from the axis of the coil towards the surface of the cone while going in perpendicular to the axis. It should be maximum on the surface of the cone. Similar type electric field should also be produced by a bar magnet. The direction of the electric field is same everywhere in the surrounding region of the coil and bar magnet and is circular about axis of the coil.

The deflections of a charged particle in the electric field of bar magnet are shown in figure 10(a). In region 'A' of the bar magnet it goes in upward direction while in the region of cones it goes in downward direction thought the field direction is same at both regions. This is because in which direction the field is increasing or decreasing means the field strength is increasing or decreasing while going away from its center will decide in which direction the particle is to be deflected. In region 'A' of the magnet, the electric field decreases away from center of the bar magnet which is illustrated in figure 10(b). In region of the electric field cone of the magnet, the electric field increases away from center of the bar magnet which is illustrated in figure 10(c).The charged particle deflections can be understood using the four deflections shown in figure 6. If the particle is coming into the strong field region then it gets deflected in the direction of the force. If the particle is going into the weak field region then it gets pushed in opposite direction of the force. If the particle gets accelerated then it gets pushed into the weak field region and if it gets decelerated then it gets pushed into the strong field region. Using these facts, the deflections in the surrounding region of the bar magnet can be understood which supports to the formation of the electric field cones.

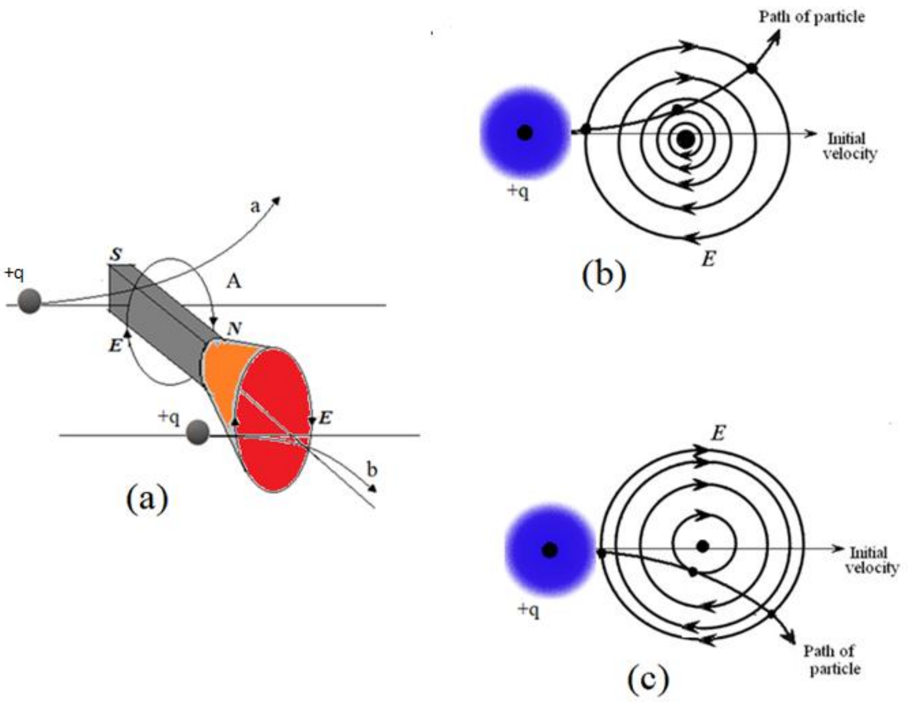


Fig. 10 (a) Deflections of a charged particle in the field of a bar magnet, (b) Circular electric field of bar magnet decreasing in magnitude away from center, (c) Circular electric field of bar magnet increasing in magnitude away from center.

Possible electric field cones at both poles of earth are shown in figure 11. Formation of aurora in ring shape at both poles of the planets (figure 12) supports to the formation of electric field in the form cones at both poles of the planets.

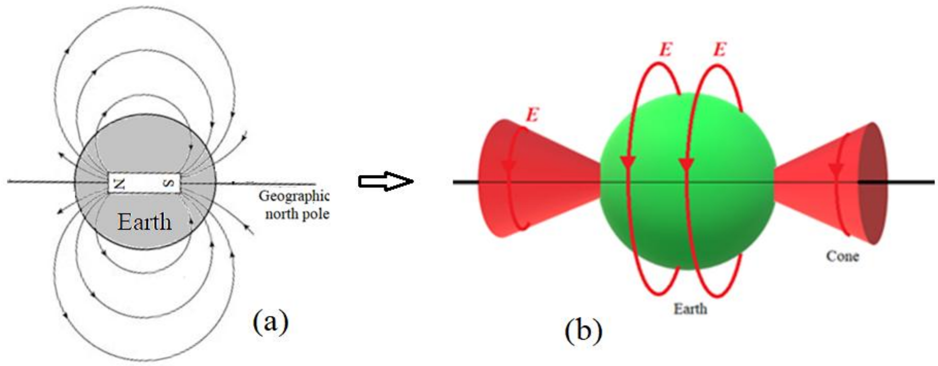
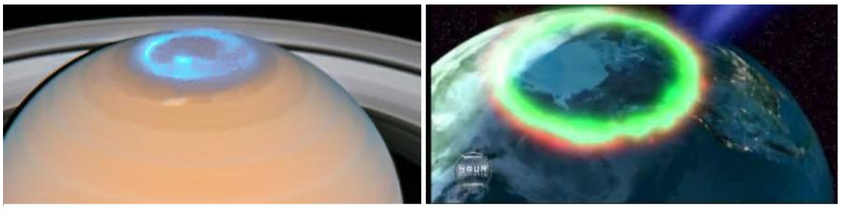


Fig. 11 Electric field of earth in absence of solar wind.



(a) Saturn (b) Earth

Fig. 12 Aurora produced at the poles of planets in the form of rings.

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V. Attraction between Poles of Bar Magnets

Attraction and repulsion between magnetic poles is an important phenomenon in magnetism. In figure 13(a), the electric force and spin direction of the electron are opposite to each other. Therefore, the electron gets dragged towards the magnet into strong electric field.

In figure 13(b), the electric field of magnet M_1 applies force on the unpaired electrons in magnet M_2 in opposite direction of their spin because of which these electrons and hence the magnet M_2 gets dragged towards magnet M_1. In similar way the electric field of magnet M_2 reacts with the unpaired electrons in magnet M_1. Thus there is no direct attraction between the magnets.

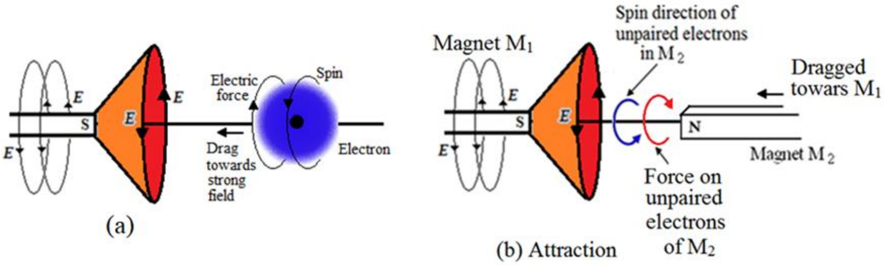

Fig. 13 Representation of attraction between two poles of bar magnets.

VI. Repulsion between Poles of Bar Magnets

In figure 14(a), the electric force and spin direction of the electron are in same direction. Therefore, the electron gets pushed away from the magnet into weak electric field.

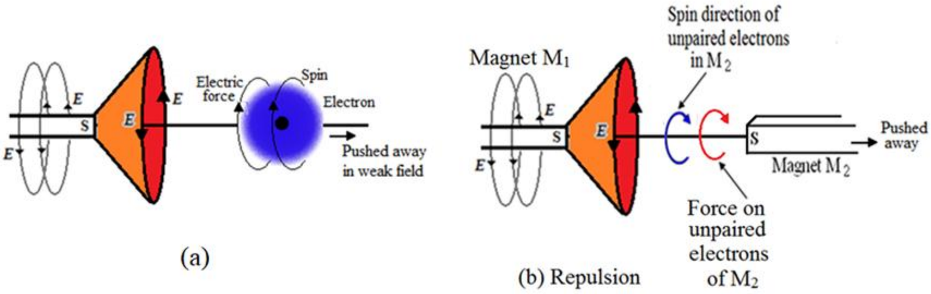

Fig. 14 Representation of repulsion between two poles of bar magnets.

In figure 14(b), the electric field of magnet M_1 applies force on the unpaired electrons in magnet M_2 in same direction of their spin because of which these electrons and hence the magnet M_2 gets pushed away from magnet M_1. In similar way the electric field of magnet M_2 reacts with the unpaired electrons in magnet M_1. Thus there is no direct repulsion between the magnets.

VII. Magnetization Produced in Magnetic Materials

Magnetization produced in magnetic materials is an important phenomenon in magnetism. Suppose a magnetic material is brought near a bar magnet. If an unpaired electron in the material possesses spin in opposite direction of the force applied by the electric field of the magnet then there will be attraction between the electron and the magnet resulting no change in the spin direction as shown in figure 15(a). There will be no change in the spin direction of all such electrons as shown in figure 15(b).

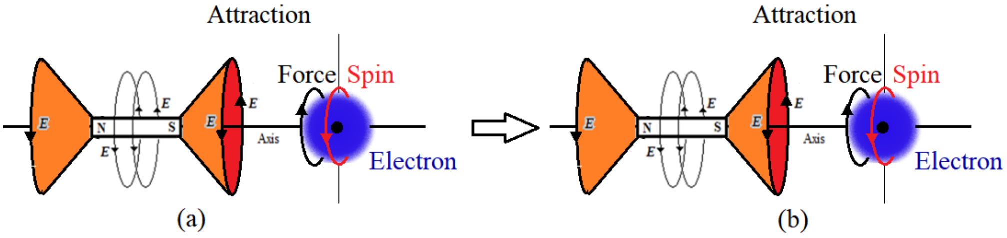

Fig. 15 Representation of magnetization produce in magnet material when the spin of an unpaired electron is in opposite direction of the electric force of the external bar magnet where spin direction remains unchanged.

If an unpaired electron in the material possesses spin in same direction of the force applied by the electric field of the external magnet then there will be repulsion between the electron and the magnet as shown in figure 16(a) resulting into flip of the spin of the electron about the vertical axis as shown in figure 16(b). It tends to align the spin of the electron in opposite direction of the force producing attraction between them and no flip of the spin further. It happens for all such electrons. In this way the spin of all unpaired electrons get aligned in opposite direction of the force produced by electric field of external magnet. Such alignment of the spin of unpaired electrons in the paramagnetic or ferromagnetic material is nothing but the magnetization. Due to the spin alignment of the unpaired electrons in the material, its net electric field becomes nonzero and it will be circular and will be in the same direction of the spin motion of these electrons or in the same direction of the electric field of the external magnet.

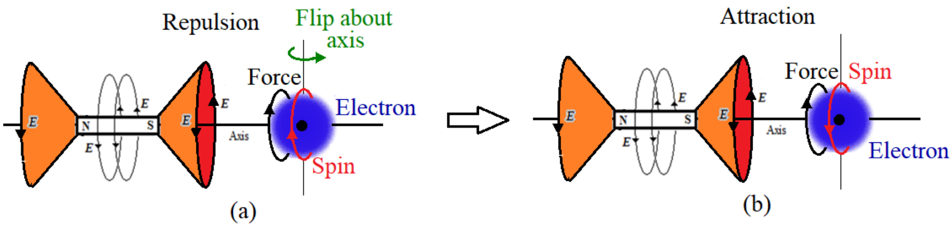

Fig. 16 Representation of magnetization produce in magnet material when the spin of an unpaired electron is in same direction of the electric force of the external bar magnet where spin direction gets flipped about vertical axis.

VIII. Reinvestigation of Field of Electromagnetic Wave Produced by an Antenna

Asymmetric electric field produces asymmetric electric force which is responsible to produce the apparent force which is always perpendicular to the velocity of the subjected charged particle and it exists only when the charged particle is in motion. Therefore, it creates possibility of the apparent force can be the true nature of magnetic force. If it is the fact then it could be experimentally verified.

Clearly the asymmetry in the electric field of an EM wave increases with increase in frequency of the wave should cause to increase in apparent force with increase in frequency of the wave. If the apparent force is the true nature of the magnetic force then, the magnetic force exerted by any electromagnetic wave, like produced by an antenna, should increase with increase in frequency of the wave which could be experimentally verified as explained below.

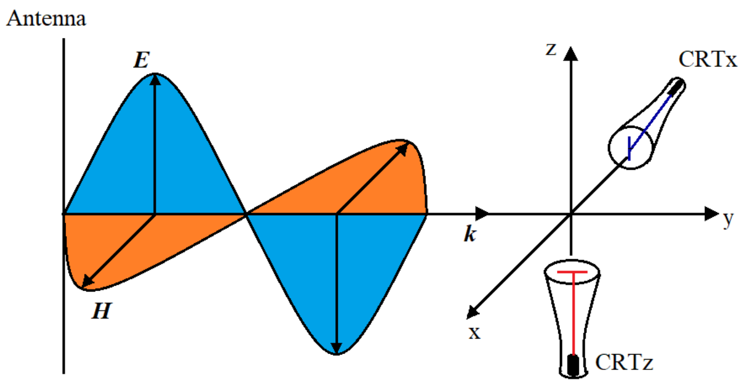

Fig 17 Experimental arrangement to determine change in electric force and magnetic force with frequency on electron beam of CRTs applied by an EM wave produced by an antenna.

Figure 17 represents the experimental arrangement to detect the dependence of magnetic force on frequency of the EM wave and phase difference between electric and magnetic fields in the wave. The antenna produces EM wave of suitable frequency and amplitude. Two cathode ray tubes (CRTs) can be used to detect response of the electric field and magnetic field in the wave. CRTx is kept perpendicular to the electric field to detect its field strength. CRTz is kept perpendicular to the magnetic field to detect its field strength.

Deflection of CRTx will be proportional to the amplitude of the electric field wave. This deflection will not depend on frequency of the wave. According to the classical electrodynamics, there will be no effect of magnetic field wave on deflection of CRTx as its electron beam is parallel to the magnetic field. By increasing the frequency of the EM waves with keeping amplitude of the wave constant, we should find there is no change in the deflection of the electron beam of CRTx.

Deflection of CRTz will be proportional to the amplitude of the magnetic field wave. According to the classical electrodynamics, this deflection will not depend on frequency of the wave, since the magnetic force does not involve any kind of frequency. Further, there should be no effect of electric field wave on deflection of CRTz as its electron beam is parallel to the electric field. By increasing the frequency of the EM waves with keeping amplitude of the wave constant, we should find no change in the deflection of the electron beam of CRTz also. But if the apparent force is actually working, then with increase in frequency of the wave the deflection of the CRTz should increase though the field strength of the wave is constant. It can be explained by figure 18.

If the apparent force is the true face of magnetic force then the magnetic field is absent in the wave. From figure 18, the electric field in the region A to C tries to decelerate the electron beam because of which the electron beam gets deflected into the strong field region. This deflection is proportional to the amplitude E_0 of the wave and inversely proportional to the distance between points A and B which is λ/4 consequently the deflection is proportional to the frequency of the wave with E_0 is kept constant. The electric field in the region between point C and D tries to accelerate the electron beam because of which the beam gets deflected into the weak field region. Here also the deflection is proportional to the frequency of the wave. This experiment will prove whether the apparent force is working as the true face of magnetic field or not.

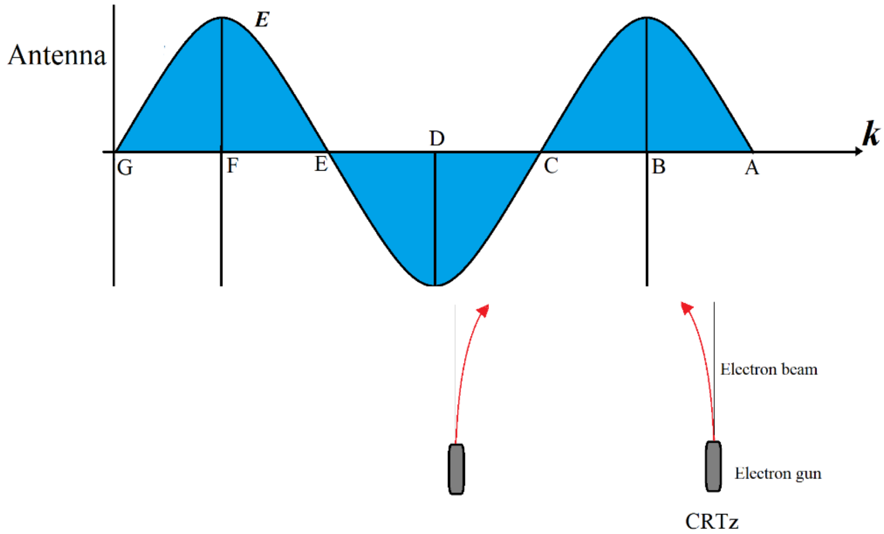

Fig. 18 Deflections of electron beam in the asymmetric electric field of EM wave.

This experiment can be performed such as, suppose the length of the electron beam of the CRT is 10cm and the accelerating voltage of the final anode is 1000volt then the frequency of the EM wave should be in the range of 1MHz to 100MHz. Produce such an EM wave by an antenna and keep the magnitude of the wave sufficiently strong so as to get deflection of electron beam in CRTs. By keeping the field strength constant and increasing the frequency of the wave from 1MHz to 100MHz in small steps and note the deflections of the CRTs at both positions. With increase in frequency we should found increase in deflection of the CRTz which will confirm the apparent force Fa produced by asymmetric electric field which is working as the magnetic force and responsible to produce the photoelectric effect. On the other hand CRTx should not show any change in the deflection. While doing the experiment we might have to do changes in the frequency range.

IX. Phase Difference Between Electric and Magnetic Field Waves

If the apparent force is actually working as the magnetic force then there can be a phase difference between electric field wave and magnetic field wave which can be understood using figure 19. When electrons are accelerated, they get pushed into weak field and when they are decelerated then they get pushed into strong electric field.

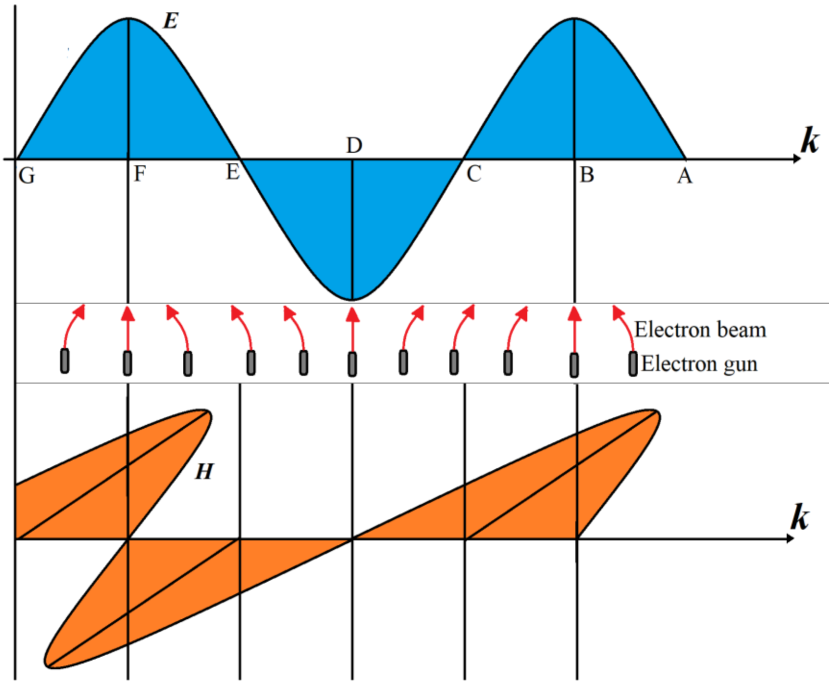

Fig. 19 Deflections of electron beam in the asymmetric electric field of EM wave showing a phase difference of 90 degrees in electric and magnetic field waves.

The electric field between A to C decelerates the electron because of which they get pushed into the strong field region. The field between C to E accelerates the electron because of which they gets pushed into the weak field region.

At positions B, D, F the electric field is symmetric, therefore, there is no deflection of electron beam indicating corresponding magnetic field should be zero. The phase difference can be experimentally verified by using same ramp voltage signal to both CRTs simultaneously. The actual phase difference between electric field and magnetic field in an EM wave should be as like shown in figure 19.

According to the existing classical electrodynamics, phase difference between electric and magnetic field waves in an EM is zero indicating that the electric field energy and magnetic field energy in the EM waves simultaneously increases and decreases and becomes zero too. But according to the expectations from the above experiment, phase difference between electric and magnetic field waves in an EM should be 90 degrees indicates that when the electric field energy increases at that time the magnetic field energy decreases. When electric field energy becomes maximum at that time the magnetic field energy becomes zero. Further when the electric field energy decreases at that time the magnetic field energy increases and becomes maximum. Thus electric field energy getting converted into magnetic field energy and vice versa which seems to be usual. Actually the electric field energy is potential energy and the magnetic field energy is kinetic energy and both are getting converted into each other as like in simple harmonic motions. EM wave is also a simple harmonic wave. Therefore, figure 20(b) should be true picture of EM waves.

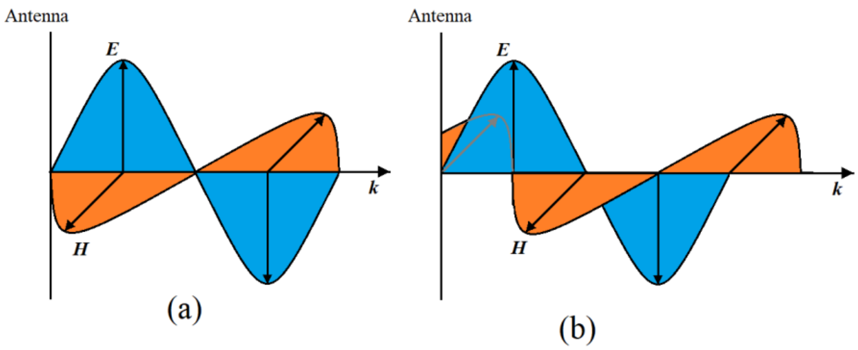

Fig 20 According to the existing classical electrodynamics, phase difference between electric and magnetic field waves in an EM should be zero. (b) According to the expectations from the above experiment, phase difference between electric and magnetic field waves in an EM should be 90 degrees.

X. Conclusion

According to the above discussions, the magnetic force should increase with increase in frequency of electromagnetic wave which should be responsible to produce the photoelectric effect. Further, there should be a phase difference of 90 degrees between the electric field wave and magnetic field wave in an EM wave. Both things are not supported by the classical electrodynamics. Further it is found that the apparent force produced due to the existence of asymmetric electric force works similar to the magnetic force implying that the apparent force can be the true face of magnetic force giving answer to the absentee of magnetic monopoles in the universe. On advent of these findings, a straight current should produce a parallel electric field and a coil and a bar magnet should produce a circular electric fields with having two electric field cones at the said poles of the magnet.

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