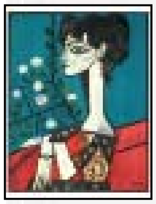
The Secrets of F=QvxB



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Abstract

The well known equation $\mathbf{F} = Q\mathbf{v} \times \mathbf{B}$ actually conceals a number of secrets about magnetism. These secrets can be uncovered with very simple mathematics that most anyone familiar with classical theory can follow.

One secret reveals that there does NOT have to be relative motion between a charge and a magnetic field to produce a force. Another secret reveals that the notion of a static magnetic field is a contradiction in terms; there can be no such construct.

These secrets are demonstrated by three well known experiments. In two of the experiments, there is NO relative motion (between magnetic fields and charges) and paradoxically a force IS developed. In the other experiment there IS relative motion and NO force is developed.

In this paper we develop the New Magnetism model [5] from $\mathbf{F} = Q\mathbf{v} \times \mathbf{B}$.

Using New Magnetism, the Homopolar Paradox [1] is finally explained. In a Homopolar generator, there are four modes of operation; of which, one seems to defy classical wisdom. In that mode, the disk and the magnet rotate together and paradoxically, power is developed. This paper shows that there is no requirement for relative motion in order for power to be developed; as such, there is no longer a paradox with respect to the Homopolar Generator.

This paper also shows that the B field abstraction is not sufficient to represent the complex "tapestry" of effects which comprise magnetic phenomena. As such, the B field abstraction and all derived manifestations are considered obsolete.

Finally, the concepts of "cutting flux lines" and "linking flux lines" become moot when the "B" field abstraction becomes obsolete.

The Secrets of F=QvxB

1 Take a close look at F=QvxB

The way to reveal the secrets of $\mathbf{F} = Q\mathbf{v}\times\mathbf{B}$ is to remove the B field abstraction. We begin by writing down the classical motional electric law (CMEL)

Step 1) $\mathbf{F} = Q\mathbf{v}\times\mathbf{B}$

In order to remember that Q and v are attributes of the charge which is reacting to the magnetic field, apply the subscript T which stands for target.

Step 2) $\mathbf{F} = Q_T\mathbf{v}_T\times\mathbf{B}$

What about the magnetic field B? B only describes an intensity and direction of flux at a given point in space. There is no inherent field velocity described by the B variable. So what is the velocity of the magnetic field at the point of the target charge? It is well known that Magnetic fields are generated by charges in motion and since a magnetic field must follow its source (the charge); then the velocity of the magnetic field is the velocity of the charge that sources the field (the source charge). Therefore, we next derive the magnetic field of a point charge from the Biot-Savart model.

Step 3) $d\mathbf{B} = \dfrac{\mu I d\mathbf{L}\times\hat{\mathbf{r}}}{4\pi|\mathbf{r}|^2}$

Realize that

$Id\mathbf{L} = \dfrac{dq}{dt}d\mathbf{L} = dq\dfrac{d\mathbf{L}}{dt} = dq\mathbf{v}$ (For v and dL in same direction)

Then substitute to arrive at

Step 4) $d\mathbf{B} = \dfrac{\mu dq\mathbf{v}\times\hat{\mathbf{r}}}{4\pi|\mathbf{r}|^2}$

Integrate both sides with respect to dq to arrive at

Step 5) $\mathbf{B} = \dfrac{\mu Q \mathbf{v} \times \hat{\mathbf{r}}}{4\pi |\mathbf{r}|^2}$

Apply the subscript S, to both Q and v, to signify the source of the magnetic field.

Step 6) $\mathbf{B} = \dfrac{\mu Q_S \mathbf{v}_S \times \hat{\mathbf{r}}}{4\pi |\mathbf{r}|^2}$

Substitute Step 6 into Step 2 and reduce

Step 7) $\mathbf{F} = \dfrac{\mu Q_S Q_T}{4\pi |\mathbf{r}|^2} \mathbf{v}_T \times (\mathbf{v}_S \times \hat{\mathbf{r}})$

Apply the well known vector identity $A \times (B \times C) \equiv (A \bullet C)B - (A \bullet B)C$

$$\mathbf{F} = \frac{\mu Q_S Q_T}{4\pi |\mathbf{r}|^2} [(\mathbf{v}_T \bullet \hat{\mathbf{r}})\mathbf{v}_S - (\mathbf{v}_S \bullet \mathbf{v}_T)\hat{\mathbf{r}}]$$

Equation 1: Resolved CMEL

Equation 1 is the point charge form of the classical motional electric law (CMEL). In the next paragraphs, Equation 1 is explored in more detail.

Note: in section 3 of this document a dogmatic interpretation is applied to CMEL which yields 4 terms.

We start this exploration of CMEL with the last term inside the brackets. This term shows that there is a force of attraction between parallel moving currents or charges (see Figure 2-1). This is no surprise since it is well known that currents moving in parallel wires (in the same direction) will develop an attractive force between them. What is surprising is that this simple derivation of classical field theory contradicts the “flux model” abstraction which has “brain washed” us to believe that there can only be force developed when there is relative motion. We will get back to this later.

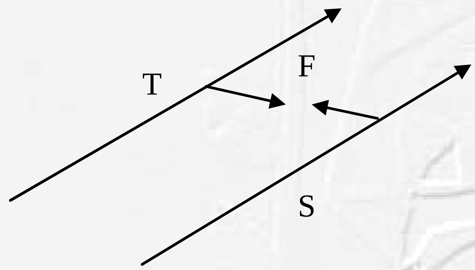

Figure 1-1: Parallel currents attract

We next look at the first term of Equation 1. This term explains that a force is induced in the target wire (Figure 1-2) as it is moved toward the current carrying source wire. This force can be expressed in terms of emf using standard techniques ($emf = \int \frac{\mathbf{F}}{Q} \bullet d\mathbf{L}$). The direction of the induced emf in the target is opposite to the direction of the current in the source.

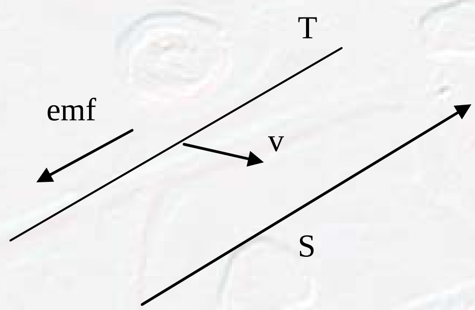

Figure 1-2: Target motion induction

What about the case where the source filament is moved instead? See Figure 1-3. Shouldn't moving the source closer to the target be identical in effect to what is shown in Figure 1-2? The answer is yes.

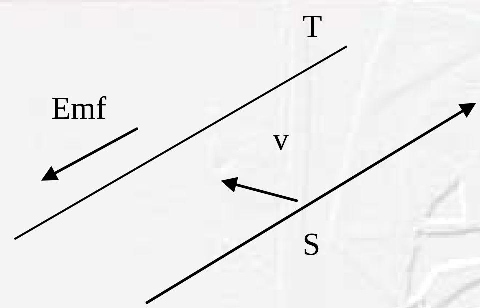

Figure 1-3: Source motion induction

Why isn't this case covered in the classical motional electric law? I'm not sure; however, this effect is well known and easily demonstrated.

In order to account for this known effect in a manner consistent with experiment, a third term is added to the equation such that the corrected equation is.

$$\mathbf{F} = \frac{\mu Q_S Q_T}{4\pi|\mathbf{r}|^2}\left[(\mathbf{v}_T \bullet \hat{\mathbf{r}})\mathbf{v}_S - (\mathbf{v}_S \bullet \hat{\mathbf{r}})\mathbf{v}_S - (\mathbf{v}_S \bullet \mathbf{v}_T)\hat{\mathbf{r}}\right]$$

Equation 2: New Magnetism (r is from source to target)

This model is called the New Magnetism [5] model of magnetism. In the book New Magnetism (http://www.distinti.com/docs/nm_bk000.pdf), this equation is derived from a very different approach.

The first two terms comprise what is known as the relative motion components. These two terms cancel when both the source and target are moving with identical velocities.

The third term is called the parallel motion component. It is maximum when charges are moving in parallel paths.

Since classical theory is dogmatically against the notion of magnetic force without relative motion; we next present three commonly known experiments which seem to benefit from the existence of the "anti-dogmatic" parallel motion component (third term). As stated previously, this component details a force which is maximum under conditions of parallel motion. It should also be remembered that this term is part of both the classical motional electric law (CMEL) and New Magnetism.

2 Applications of the parallel motion component

The following three experiments are based on well known observations of electromagnetic phenomena. These experiments are demonstrative of cases where force (or emf) is developed in spite of the fact that there is no relative motion between a charge and a magnetic field.

2.1 Parallel moving charges

Suppose two charges are moving parallel at some velocity v as shown in the following diagram.

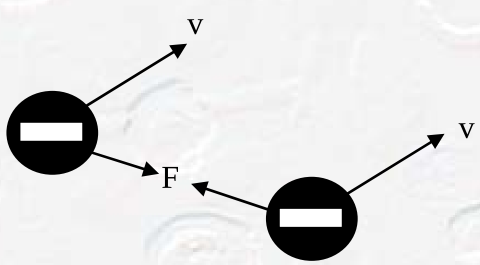

Figure 2-1: Parallel moving charges

The repulsive force between the charges is calculated from Coulomb's law and the attractive force is the parallel motion component of New Magnetism. Therefore, we begin by summing these two equations to arrive at:

Step 1) $$\mathbf{F} = \frac{Q_S Q_T}{4\pi\varepsilon|\mathbf{r}|^2}\hat{\mathbf{r}} - \frac{\mu Q_S Q_T}{4\pi|\mathbf{r}|^2}[(\mathbf{v}_S \bullet \mathbf{v}_T)\hat{\mathbf{r}}]$$

Because of the geometry of the problem, it can be reduced as follows

Step 2) $$F = \frac{Q_S Q_T}{4\pi r^2}\left[\frac{1}{\varepsilon} - \mu v^2\right]$$

This can be rewritten as

Step 3) $$F = \frac{Q_S Q_T}{4\pi\varepsilon r^2}\left[1 - \frac{v^2}{C^2}\right]$$

The repulsive Coulomb forces are cancelled by the magnetic force as the velocity approaches the speed of light. Perhaps this is the mechanism that allows electron beams to resist scattering due to Coulomb forces?

It is important to realize that there is no relative motion between the charges; therefore, there is no relative motion between one charge and the field produced by the other charge; and yet, there is a magnetic force. This seems to contradict the relative motion requirement of classical dogma.

This is the same mechanism that allows current in parallel wires to attract. With that said, there are classical theorists who believe that the attraction between parallel wires is due to the magnetic field of the moving charges in one wire acting on the non-moving positive charges in the other wire. How can this be? According to CMEL there is no term that predicts a force along r in which v_T is zero; ironically, the new term introduced by New Magnetism seems to predict what the classical theorists want to believe. Unfortunately for the classical theorists, the following section demonstrates that the new term completely cancels in a stationary closed loop.

Thus according to CMEL (and New Magnetism), the force between two parallel moving charges is due to the Parallel Motion component which does not require relative motion in order to develop a force.

2.2 Loop of wire and charge

The experiment shown in the following diagram is comprised of a stationary charge and a stationary loop of wire with a constant current (I). The magnetic field of the wire is said to be "Stationary" or "Static" since the loop is not in motion; however, because a magnetic field follows its source; and, since the source of a magnetic field is a charge in motion; and, since a current carrying loop is comprised of many charges in motion; then, the magnetic field of a current loop is a complex "tapestry" of small magnetic fields in motion. Since the field from a charge is an inverse square phenomenon, then the velocity of the field at the target charge is predominantly due to the charges on the near side of the loop.

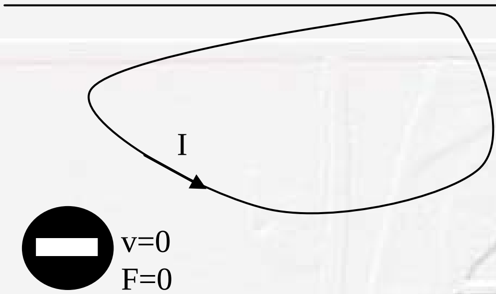

Figure 2-2: Charge and current carrying loop

It is well known that the magnetic field developed from a stationary closed loop of wire does not affect a stationary charge. Therefore, with regard to the previous section, the classical theorists can not make the claim that the moving charges in one wire affect the stationary charges in the other wire.

So how can there be no force acting on the charge when there is relative motion between the charge and the field developed by the charges circulating in the stationary path of the wire?

The key is that there is no NET force acting on the charge. By examining each term of New Magnetism it is possible to show that no net force exists.

Terms 1 and 3 show no force acting upon the target when the velocity of the target ($\mathbf{v}_T$) is zero. This leaves just the second term ($(\mathbf{v}_S \bullet \hat{\mathbf{r}})\mathbf{v}_S$).

In the book New Magnetism chapter 10 it is shown that the $(\mathbf{v}_S \bullet \hat{\mathbf{r}})\mathbf{v}_S$ term is completely cancelled in the above experiment. Since all magnetic terms are either zero or completely cancel, then there is no net force on the charge due to the magnetic field created by the wire.

If the loop and charge were set into motion with uniform and identical velocity such that the circulation path does not change relative to the charge; there would still be no NET force on the charge. This is a much more complicated case which is indirectly covered in the book New Magnetism.

If the wire were moved toward the charge, then the path of circulation with respect to the charge is now changing with respect to time; therefore, the $(\mathbf{v}_S \bullet \hat{\mathbf{r}})\mathbf{v}_S$ term will induce a force on the target.

To recap:
If the path that the current circulates through does not change in time (relative to the charge) then there will be no net effect on the charge. But this is only true for good conductors (see the book New Magnetism for the reason why).

2.3 The Homopolar Paradox

The following experiment has been a bane to modern science the 1830s. This is due to the fact that the experiment seems to contradict classical electrodynamics [1,2]. As to be shown, the third term of New Magnetism (which is derived from classical theory) is able to explain this device. We have been kept in the dark for the past 200 years because of misguided dogma which requires relative motion between a magnetic field and a conductor for emf to be developed.

To recap the experiment:
Faraday developed a generator consisting of a disk magnet coaxial to a conductive disk similar to the diagram shown in Figure 2-3. This generator is called a Homopolar generator because it only uses one pole of the magnet.

There are 4 modes of operation of the Homopolar Generator (HPG); the results of which comprise what is known as Faraday's Final Riddle: Does a magnetic field move with the magnet? [1]

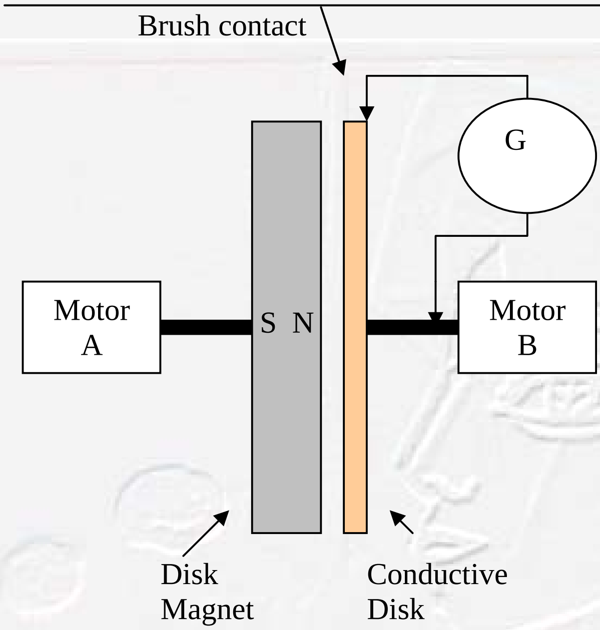

Figure 2-3: Faraday's homo-polar generator

The generator in Figure 2-3 is comprised of a disk magnet attached to a motor (A) and a conductive copper disk attached to motor (B). The disks are placed next to each other to allow them to rotate coaxial to each other. A stationary galvanometer is connected between the edge of the conductive disk and the shaft of motor B with brush contacts. The Galvanometer enables the operator to detect radial current generated in the disk (An indication that power is being generated).

There are four modes of operation of the Homopolar generator. In the following descriptions, the disk magnet is referred to as the magnet and the conductive copper disk is referred to as the disk.

In the first mode of operation, both the disk and the magnet are stationary. In this mode of operation, the Galvanometer does not detect the flow of current and thus we conclude that there is no power generated.

In the second mode of operation, the magnet is stationary and the disk is rotated by motor B. In this mode, the galvanometer detects power generated in the disk. A normal reaction is to conclude that power is generated when there is relative motion between the disk and the magnet.

In the third mode of operation, the magnet is rotated by motor A and the disk is stationary. One might try to predict that power should be generated since there is relative motion between the disk and the magnet (such as in mode 2); however, no power is detected.

In the fourth mode of operation, both the magnet and the disk are rotated together. Again, one may conclude that since there is no relative motion between the disk and the magnet (such as in mode 1) that there should be no power generated; however, power is generated.

Other explanations
Since the fourth mode of operation seems to contradict relativistic physics and electrodynamics, many [2] have tried to claim that power is developed from relative motion between the magnetic field and the stationary closing path (the bush and galvanometer loop). This seems to solve the problem except that in section 2.2 it is shown that a charge with zero velocity will not be affected by the magnetic field of a current which circulates through a path that does not change relative to the charge (a static path). Since Maxwell teaches us that a disk magnet has the same field characteristics as a circular loop of wire [3,4], and finally, since the rotation of the magnet by the motor does not displace the "edge current[4]" from its conduction path, then there can be no effect on the charges in the stationary closing path.

A better explanation
Since the field of the magnetic is generated by the motion of charges in a closed stationary path, then it is impossible for this magnetic field to affect stationary charges (demonstrated previously). Thus it is impossible for the stationary closing path to be the source of the emf that is measured at the output. Only charges in motion can reaction to the "stationary" magnetic field; consequently, the spinning disk provides the source of moving charges which react to the magnetic field and provide the emf at the output. This is demonstrated in chapter 9 of the book New Magnetism [5]. The motion of the magnet (assuming the magnet has perfectly uniform edge current) has no relevance to the power developed in the system. It is only the velocity of the disk that matters. This is consistent with the observed output of the device.

3 A dogmatic interpretation

A logical diversion is to wonder what would happen if we rigorously applied classical dogma to $\mathbf{F} = Q\mathbf{v}\times\mathbf{B}$. Since classical dogma stipulates that force is only developed when there is relative motion between a charge and a field, then it is only proper that we should include this relative motion in the equation since it is not already there. Accounting for the velocity of the field gives us the following variation:

Step 1) $\mathbf{F} = Q_T(\mathbf{v}_T - \mathbf{v}_B)\times\mathbf{B}$

Then substitute B using Biot-Savart as done before, thus

Step 2) $\mathbf{F} = \frac{\mu Q_S Q_T}{4\pi|\mathbf{r}|^2}(\mathbf{v}_T - \mathbf{v}_B)\times(\mathbf{v}_S \times\hat{\mathbf{r}})$

Applying the same vector identity

Step 3) $\mathbf{F} = \frac{\mu Q_S Q_T}{4\pi|\mathbf{r}|^2}[((\mathbf{v}_T - \mathbf{v}_B)\bullet\hat{\mathbf{r}})\mathbf{v}_S - ((\mathbf{v}_T - \mathbf{v}_B)\bullet\mathbf{v}_S)\hat{\mathbf{r}}]$

Substitute v_B with v_S using the assumption that the velocity of the source field must be equal to the velocity of the source charge.

Step 4) $\mathbf{F} = \frac{\mu Q_S Q_T}{4\pi|\mathbf{r}|^2}[((\mathbf{v}_T - \mathbf{v}_S)\bullet\hat{\mathbf{r}})\mathbf{v}_S - ((\mathbf{v}_T - \mathbf{v}_S)\bullet\mathbf{v}_S)\hat{\mathbf{r}}]$

Expanding the terms

$$\mathbf{F} = \frac{\mu Q_S Q_T}{4\pi|\mathbf{r}|^2}\left[(\mathbf{v}_T\bullet\hat{\mathbf{r}})\mathbf{v}_S - (\mathbf{v}_S\bullet\hat{\mathbf{r}})\mathbf{v}_S - (\mathbf{v}_S\bullet\mathbf{v}_T)\hat{\mathbf{r}} + |\mathbf{v}_S|^2\hat{\mathbf{r}}\right]$$

Equation 3: Dogmatic interpretation of CMEL

Upon inspection, it is clear to see that the first three terms agree with New Magnetism. The fourth term $+|\mathbf{v}_S|^2\hat{\mathbf{r}}$ is new and interesting.

This model teaches us that there are no effects between two charges traveling in parallel. This might seem like victory for classical theory except that the dogmatic interpretation predicts the following strange experimental outcomes:

1) Parallel wires with current in the same direction ($\mathbf{v}_S$=$\mathbf{v}_T$) have virtually no attraction ($-(\mathbf{v}_S \bullet \mathbf{v}_T)\hat{\mathbf{r}} + |\mathbf{v}_S|^2 \hat{\mathbf{r}} = 0$).
2) Parallel wires with currents in opposite directions ($\mathbf{v}_S$=-$\mathbf{v}_T$) have two times the repulsive force ($-(\mathbf{v}_S \bullet \mathbf{v}_T)\hat{\mathbf{r}} + |\mathbf{v}_S|^2 \hat{\mathbf{r}} = 2|\mathbf{v}_S|^2 \hat{\mathbf{r}}$) than what is expected.
3) According to the new term, the mobile charges in a wire will repel like charges and attract dislike charges. This attraction or repulsion is the same regardless of the direction of the current. This means that a current carrying wire (closed loop) should be able to affect a stationary charge – but this is known not to be true.
4) How do we explain the Homopolar Paradox now?
5) Many others

It should be obvious to the experimenter that the above effects are incorrect with regard to the well know experiments.

For the sake of allowing the imagination to wander freely, let us look at the fourth term alone.

$$\mathbf{F} = \frac{\mu |\mathbf{v}_S|^2 Q_S Q_T}{4\pi |\mathbf{r}|^2} \hat{\mathbf{r}}$$

Then compare the above to Coulomb’s Model which can be expressed as

$$\mathbf{F} = \frac{\mu C^2 Q_S Q_T}{4\pi |\mathbf{r}|^2} \hat{\mathbf{r}}$$

Perhaps at some Quantum “sub-level” the electrostatic force may be explained as the “4th term of Magnetism”; however, at the electronic scale (the scale of electrons and above – the scale which is important to electrical engineers such as myself) this fourth term seems to predict effects that are just not observed.

Special note for followers of New Electromagnetism: If you apply the 4 term derivation shown in Equation 3 to the BMP (omit Coulomb's Law); you will get a system which is stable for all velocities and all radii. Therefore, there is no way to deduce $E=MC^2$, black hole radius or time dilation. It is my present belief that the 4^{th} term is not viable (though I would love to be proven wrong on this).

4 Conclusion

Classical electromagnetic dogma requires relative motion between a charge and a magnetic field in order for a force to be produced. Why? The resolved version of CMEL (Equation 1) shows that this is not true since it contains the parallel motion term. When attempting to eliminate the parallel motion term through strict dogmatic interpretation of CMEL (Equation 3) we get an equation that predicts outrageous things. So how did this dogmatic requirement (that only relative motion can cause magnetic force) come about?

I believe that this dogmatic requirement evolved from two misinterpretations of physics that were turned into “gospel” (or dogma).

The first is the concept of a “static magnetic” field. In the early days, people used iron filings to “observe” the “flux lines” about a magnet. Because the iron filings created “lines” and because the “lines” lines did not move relative to the magnet, then it was assumed that the magnetic field of a stationary magnet is itself stationary. But this can not be true if we consider that a magnetic field follows its source (the moving charge) and because there is no magnetic field unless charges move; then all magnetic fields are in motion. More precisely, magnetic fields from wires or magnets are comprised of a vast quantity charges in motion. Each charge in motion produces a small magnetic field which is itself in motion; as such, a real magnetic field is a complex “tapestry” of individual moving magnetic fields. Therefore, the classical concept of a stationary (or static) magnetic field is an oxymoron.

The second is the B field abstraction. We adopted the “flux line” abstraction because the iron filing in a magnetic field arranged themselves into lines. The “flux line” abstraction begets the B field abstraction which is a concentration and direction of “flux lines”. If it is correct to conclude that a magnetic field is composed of flux lines based on the behavior of iron filings; then it should also be proper to conclude that air is composed of rippled dunes because of its effect on beach sand.

Even if you still want to use the “B” field abstraction you must remember that it only gives the concentration and direction of field lines; it does not tell you the velocity of the magnetic field. It can not account for the complex "tapestry" of motions required to calculate the complete set of magnetic interactions.

Furthermore, the "B Field" abstraction is only valid for the first and third terms of New Magnetism which means that it is only applicable to stationary closed loop systems.

It is therefore the opinion of this author that the B field abstraction is obsolete. This obsolescence includes the derived functions known as the static and vector magnetic potentials. The obsolescence of the B field abstraction begets the obsolescence of "flux lines". With New Magnetism it is no longer necessary to bother with the notions of "flux lines being cut" or "flux lines being linked" since the B field abstraction is done away with. To be clear: magnetic fields do exist; however, the B field abstraction is not a sufficient representation of such complex phenomena.

It is ironic that both New Magnetism and $\mathbf{F} = Q\mathbf{v}\times\mathbf{B}$ share the parallel motion term ($-(\mathbf{v}_S \bullet \mathbf{v}_T)\hat{\mathbf{r}}$). This term predicts that a force is developed between parallel moving charges (not necessarily parallel moving systems – see book New Magnetism for details). Thus, a force can occur without the absolute requirement of relative motion. This term, hidden by centuries of ingrained dogma, enables us to explain such things as the Homopolar Paradox [1] and the reason why electron beams resist scattering due to Coulomb forces.

Classical electrodynamics has a conundrum on its hands due to the fact that classical text books publish this version of CMEL $\mathbf{F} = Q\mathbf{v}\times\mathbf{B}$ while explaining CMEL from a dogmatic standpoint which works out to this equation $\mathbf{F} = Q_S(\mathbf{v}_S - \mathbf{v}_B)\times\mathbf{B}$. As demonstrated in this paper, these two equations are very different. Furthermore, neither of these two equations properly account for known magnetic effects.

A careful accounting of magnetic effects compels one to conclude that there are both relative and parallel motion components of magnetism. The New Magnetism model has been carefully developed to address these effects.

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3) James Clerk Maxwell: “A Treatise on Electricity & Magnetism,” Dover Press, Volume 2, Articles 423 and 492. See chapter 8 of the Book New Magnetism for a more advanced treatment of Maxwell’s Magnet model.
4) Robert J. Distinti: “New Magnetism” Area-46 Publishing, 1st edition, Chapter 8 explains the definition of the “Edge current” with regard to magnets.
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