SECTION 5

The Action of Matter: The Magnetic Effect Ampere's Law

When it is at rest, the interaction of a *Spherical-Center-of-Oscillation* with its environment, other centers, is the electrostatic Coulomb effect. But, when the center is in motion, there is an additional effect, the magnetic effect.

STATIC MAGNETIC BEHAVIOR

Static magnetic behavior is the interactive effect of one center on another, due to both at constant velocity. A center so in motion exerts on another center a second force due to the motion. The direction of this interactive force is summarized in Figure 5-1 on the following page: a pair of electric currents (flows of electric charges, flows of *Spherical-Centers-of-Oscillation*) in various orientations relative to each other.

There are five basic cases of relative orientation of the two currents interacting. Any other situation can be resolved into some combination of them. In each case the analysis is of the effect of current #1 on current #2. Of course, exactly analogous reasoning would treat the effect of current #2 on #1.

Both effects occur simultaneously just as in the earlier discussion of Coulomb's Law each center is in both source and encountered roles simultaneously even though the action is described in terms of only one of the roles at a time. I is the commonly used symbol for current. F_M is the magnetic force.

Electric current being a flow of electric charges, one can speak of current or of some-quantity-of-charges-with-some-velocity. The following discussion must use both terminologies in order to relate the one to the other. A positive current in a given direction corresponds to positive charges flowing in that direction and equally corresponds to negative charges flowing in the opposite direction. Each charge is a *Spherical-Center-of-Oscillation.*

The magnitude of the static magnetic force, F_M, is given by Ampere's Law, equation *5-1* for Case #1 or #2.

$$F_M = \frac{\mu}{2\pi} \cdot \frac{I_1 \cdot I_2}{R} \cdot L \tag{5-1}$$

where: L = the length of each of the two parallel current paths over which the force acts,

R = the distance between the two parallel paths,

μ = the permeability, a magnetic parameter of the space between the two current paths (as before in the discussion of the velocity of light).

Case 1 - The currents are in the same direction.

Magnetic effect is attraction.

Case 2 - The currents in opposite directions.

Magnetic effect is repulsion.

Case 3 - Current #2 moving perpendicular to & toward current #1.

Magnetic effect is deflection of #2 in the opposite direction to that of #1.

Case 4 - Current #2 moving perpendicular to & away from #1.

Magnetic effect is deflection of #2 in the same direction as that of #1.

Case 5 - No current #2. Its charges are at rest relative to current #1.

No magnetic effect.

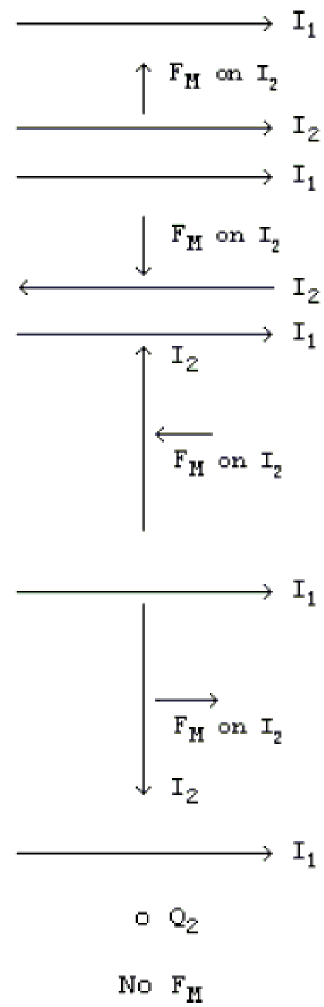

Figure 5-1

The magnetic effects are in addition to the electrostatic (Coulomb) effects of the same charges. That is, the charges, the *Spherical-Centers-of-Oscillation* whose motion is the current that produces the magnetic effects, have their natural (Coulomb) effect on each other when in motion as well as when at rest.

However, their motion changes the amount and direction of that effect and that change is the magnetic effect. To evaluate the magnetic force, then, it is necessary to examine the changes caused in the electrostatic force by the motion of those charges. If F_T is defined as the total interaction force, the combined effect of the electrostatic force, F_E, as it would be for those charges at rest and the magnetic force, F_M, due to their motion is, then

(5-2) $\mathbf{F_T = F_E + F_M}$

where: F_T = the total interaction force between the charges,

F_E = the Coulomb force when the charges are at rest,

F_M = the magnetic force,

where the bold type indicates that the quantities have both magnitude and direction (are "vector" quantities) and both the magnitude and direction must be taken into account.

The analysis must therefore be: first an evaluation of the interactive force with the current's charges at rest, F_E ; then an evaluation of F_T , the interactive force in the same configuration but with the charges in motion at velocity, v; and, finally, the comparison of those two results to obtain the magnetic effect, F_M.

The natural geometry of the situations to be analyzed, the cases of Figure 5-1, makes the overall problem quite complicated. There is a great variety of configurations: the spherical form of each charge, the cylindrical symmetry of the currents and such currents in some cases perpendicular to each other, resulting magnetic forces in third directions, etc. As a result there is almost no way to obtain simple mathematical descriptions and analyses of what is actually happening. The real physical processes are direct and simple, but whether the mathematics is performed in rectangular, spherical or cylindrical coordinates some of the aspects of the problem will not be conveniently accommodated so that the mathematical expressions tend to become difficult.

Dividing equation *5-1* by the path length, L , which is the length of current path I_1, the magnetic force of I_1 (the effect of its entire path length) on a unit length of I_2 (a minute length increment) is as in equation *5-3*, below.

(5-3)
$$F_M = \frac{\mu}{2\pi} \cdot \frac{I_1 \cdot I_2}{R} \qquad \text{[per unit length.]}$$

For equations *5-1* and *5-3* to be valid the actual path length, L, must be much greater than the minute length increment so as to prevent "end" effects. Theoretically the two current paths are infinitely long and a short section in the middle is being considered. That is, equation *5-3* expresses the magnetic effect of all of the electric current of I_1 over its entire path length, L (where because the path of I_1 is so long the effect of the distant parts is negligible), acting on a unit length section of I_2.

Each of the currents, I_1 and I_2, is a stream of charges moving at velocity, v, as shown in Figure 5-2, below.

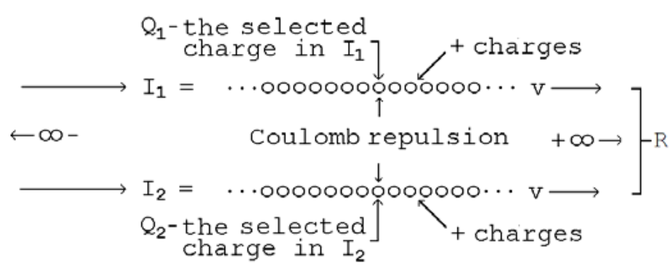

Figure 5-2

If Q_1 is the increment of charge in a unit length of the stream of charges that is I_1 and Q_2 is that for I_2 , then, per Coulomb's law, the electrostatic force that acts on charge increment, Q_2 , in I_2 due to the directly opposite charge increment, Q_1 , in I_1 is

(5-4)
$$F = \frac{Q_1 \cdot Q_2}{4\pi \cdot \varepsilon \cdot R^2} \qquad \text{[Coulomb's Law.]}$$

Of course, Q_2 is similarly affected by all of the other charges in I_1 , not just Q_1 .

Since length increments and force per unit length are being treated, the increments of charge Q_1 and Q_2 must be replaced with charge-per-unit-length, ρ_1 and ρ_2, so that, when multiplied by length increments charge amount is obtained.

The amount of charge, Q, located in length increment, dx, is

(5-5) $$Q = \rho \cdot dx$$

To analyze the total electrostatic effect of all of the charges of which I_1 is composed on a single charge increment in I_2 the analysis is as in Figure 5-3. In the figure R and $R(x)$ are radial distances between charge increments $Q = \rho \cdot dx$, that is R and $R(x)$ are the radial charge separation distance that appears in the denominator of Coulomb's law. The $dF(x)$ is the incremental Coulomb effect of a charge increment in I_1 on the selected charge increment in I_2. F_r is the peak value that $dF(x)$ attains (when its $[R(x)]^2$ in the Coulomb's law denominator is a minimum, R^2).

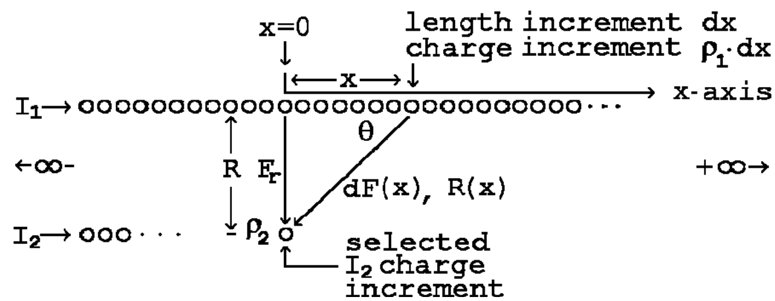

Figure 5-3

From Coulomb's law, the magnitude of $dF(x)$, the increment of the force, $F(x)$, exerted on the charge increment ρ_2 by $(\rho_1 \cdot dx)$, the amount of charge of I_1 that is located in length increment, dx, is

(5-6) $$dF(x) = \frac{(\rho_1 \cdot dx) \cdot \rho_2}{4\pi \cdot \varepsilon \cdot [R(x)]^2}$$

When $x=0$ so that $R(x)=R$ the rate of $dF(x)$ per dx is the pure "sideward" value, which equals the rest value and will be defined as F_r,

(5-7) $$\frac{dF(x)}{dx} = \frac{\rho_1 \cdot \rho_2}{4\pi \cdot \varepsilon \cdot R^2} \equiv F_r$$

so that equation $5\text{-}6$ then becomes

(5-8) $$dF(x) = F_r \cdot dx \cdot \frac{R^2}{[R(x)]^2}$$

From the right triangle $[\rho_2 - dx - x=0]$ in Figure 5-3 the sides of which triangle are R, x, and the hypotenuse, $R(x)$,

(5-9) $$R(x) = \sqrt{x^2 + R^2} \quad \text{[law of Pythagoras]}$$

so that equation $5\text{-}8$ becomes

(5-10) $$dF(x) = F_r \cdot \frac{R^2}{x^2 + R^2} \cdot dx$$

This force magnitude is directed diagonally to the lower left in Figure 5-3. That is, the charges in I_1 and I_2 are of the same sign and repel each other. The charge increment of I_1 at dx repels ρ_2 as shown in the figure. Depending on which charge increment of I_1 is considered, the angle at which the force increment, $dF(x)$, acts varies.

Consequently, the analysis must be broken down into two orthogonal components. In terms of Figure 5-3 those components will be "horizontal", that is parallel to the figure's x-axis, and "vertical", at right angles to "horizontal". A quantity annotated with a horizontal arrow above it will mean that the "horizontal" component of the overall vector quantity is being treated. A quantity annotated with a vertical arrow to its left will mean that the "vertical" component is being treated.

The magnitudes of the components, $\overrightarrow{dF}(x)$ and $\uparrow dF(x)$ relate to the overall vector quantity, $\mathbf{dF(x)}$, as

(5-11) $$\overrightarrow{dF}(x) = \mathbf{dF(x)} \cdot \frac{x}{R(x)} = \mathbf{dF(x)} \cdot \frac{x}{[x^2 + R^2]^{½}}$$

$$\uparrow dF(x) = \mathbf{dF(x)} \cdot \frac{R}{R(x)} = \mathbf{dF(x)} \cdot \frac{R}{[x^2 + R^2]^{½}}$$

CASES 1,2 AND 5

The Static Force (The Charges At Rest)

From $x=-\infty$ to $x=0$ the horizontal components are all directed to the right. From $x=0$ to $x=+\infty$ they are all directed to the left. Summed up from $x=-\infty$ to $x=+\infty$ the horizontal components cancel out.

(5-12) $$\overrightarrow{F_E} = 0$$

If the vertical components, $\uparrow dF(x)$, are summed over that range the result will be the total electrostatic force of the charges in I_1 on a single charge increment in I_2, the force being sought.

Substituting $dF(x)$, equation $5\text{-}10$ for $\mathbf{dF(x)}$ in the expression for $\uparrow dF(x)$, equation $5\text{-}11$, yields the increments to be summed over the range $x=0$ to $+\infty$.

(5-13) $$\uparrow dF(x) = F_r \cdot \frac{R^3}{[x^2 + R^2]^{1½}} \cdot dx$$

It will become necessary to treat the region to the left, the $[x \le 0]$ region, separately from the region to the right, the $[x \ge 0]$ region. The analysis is restated as two problems, one for the range $x=-\infty$ to 0 and one for the range $x=0$ to $+\infty$.

See Appendix D, *Integration Details for Magnetic Effect Calculations, Part 1*.

(5-14) $$\uparrow F_E = \int_{-\infty}^{0} \uparrow dF(x) + \int_{0}^{+\infty} \uparrow dF(x)$$

$$= \int_{-\infty}^{0} F_r \cdot \frac{R^3}{[x^2 + R^2]^{1½}} \cdot dx + \int_{0}^{+\infty} F_r \cdot \frac{R^3}{[x^2 + R^2]^{1½}} \cdot dx$$

$$= \pm R \cdot F_r + \pm R \cdot F_r = 2 \cdot R \cdot F_r$$

By substituting in the value of F_r from equation $5\text{-}7$, one obtains

(5-15) $$\uparrow F_E = 2 \cdot R \cdot F_r = 2 \cdot R \cdot \frac{\rho_1 \cdot \rho_2}{4\pi \cdot \varepsilon \cdot R^2} = \frac{\rho_1 \cdot \rho_2}{2\pi \cdot \varepsilon \cdot R}$$

The ratio of the magnitudes, F_M/F_E, is the F_M of equation 5-3 divided by the F_E of equation *5-13*.

(5-16)
$$\frac{F_M}{F_E} = F_M \cdot \frac{1}{F_E} = \left[\frac{\mu}{2\pi} \cdot \frac{I_1 \cdot I_2}{R}\right] \cdot \left[\frac{2\pi \cdot \varepsilon \cdot R}{\rho_1 \cdot \rho_2}\right] = \mu \cdot \varepsilon \left[\frac{I_1 \cdot I_2}{\rho_1 \cdot \rho_2}\right]$$

Since current is charge flow per unit time, then

(5-17) $$I_1 = \rho_1 \cdot v_1 \text{ and } I_2 = \rho_2 \cdot v_2$$

where v_1 and v_2 are the velocities of the charges in I_1 and I_2. Using these and, letting $v_1 = v_2 = v$ for simplicity then

(5-18)
$$\frac{F_M}{F_E} = \mu \cdot \varepsilon \left[\frac{[\rho_1 \cdot v_1] \cdot [\rho_2 \cdot v_2]}{\rho_1 \cdot \rho_2}\right] = \mu \cdot \varepsilon \cdot v^2$$

is obtained. Finally recognizing that $c^2 = 1/_{\mu \cdot \varepsilon}$ and canceling the identical ρ's the following is obtained.

(5-19)
$$\frac{F_M}{F_E} = \frac{v^2}{c^2} \qquad \text{or} \qquad F_M = \frac{v^2}{c^2} \cdot F_E$$

Although this analysis was performed only for Case 1, it is valid for all 5 cases. The magnitude of the magnetic force is the same (for analogous values of the currents, etc.) in all of Cases 1 - 4, and is zero, of course, for Case 5. Likewise, the simplifying assumption that the velocity of the charges in each of the current flows is the same does not change the general validity.

The analysis so far, while developing a somewhat new result and taking a somewhat new point of view, is nevertheless entirely a result of and performed in terms of traditional 20th Century physics. The relationship, equation *5-18*, expresses the magnitude of the change to the electrostatic effect that produces the magnetic effect.

The Magnetic Force (The Charges In Motion)

Now it is necessary to investigate how this comes about from the actions of *Spherical-Centers-of-Oscillation*. In the above analysis, while the velocity of the charges was indicated in the figure, the velocity was taken to be zero for F_E and the magnetic effect, F_M, was obtained from equation *5-2*, the traditional Ampere's Law. The analysis that produced F_E must now be performed again but with treating the charges as *Spherical-Centers-of-Oscillation* and modifying $F(x)$ (and, of course, $dF(x)$) as appropriate to the behavior of centers in motion at velocity v.

The magnetic force, alone, cannot be independently calculated. Rather, it can only be found by calculating the total interactive force with the charges in motion, F_T, and subtracting from that the portion that occurs when the charges are not in motion, the F_E just obtained. That is, from equation *5-2*,

(5-20) $$\mathbf{F_T} - \mathbf{F_E} = \mathbf{F_M}$$

Since velocity is now also a variable the symbols $F(x)$ and $dF(x)$ will be replaced with $F(v,x)$ and $dF(v,x)$. Subtracting F_E of equation *5-13* from this new F_T, the F_M portion can be obtained (taking account of direction, i.e. a vector subtraction by components). The magnitude of that F_M should be the same as obtained from Ampere's Law and that is most easily verified by taking the magnitude ratio F_M/F_E, which should be the same as equation *5-18*, which was obtained using the methods of traditional 20th Century physics.

As developed in the preceding Section 4*, The Action of Matter: Motion and Relativity,* the motion of a center at constant velocity results in changes in the propagated wave and in the center's own oscillation. Of interest here is the effective value of the charge. It is the variation in the effective value of the charge, Q $(\rho \cdot dx)$, entering into the calculation of the net force effect per equation *5-6*, that produces the change.

Now, however, unlike the development in and following equation *5-6*, Q is not a constant so that F_r is not constant and this variation due to velocity must be included in the expression for $F(x)$ (and $dF(x)$) as used in equation *5-14*, above, namely the new quantity $F(v,x)$ (and $dF(v,x)$).

In the prior section it was shown that the forward propagated wave is reduced by the factor $[1-{}^{v}/c]$ because of the forward propagation at $c' = c-v$ and that the rearward propagated wave is analogously changed by the factor $[1+{}^{v}/c]$. It was also shown that the "throwing forward" of the forward wave by the center's velocity and the "negative" of that for the rearward wave changed the net force effect of the wave by a "force component" equal to $[{}^{v}/c] \cdot F_r$, positive in the forward direction and negative in the rearward direction (where F_r is the force delivered at the same distance but from the center at rest or to its side).

These changes are summarized in Figures 5-4 and 5-5 which depict the wave propagated by the source center, Q_1 and the encountered center, Q_2 in the present analysis. The "force component" due to the center's velocity is F_{fc} . Since the force effect of the wave and the center is directly proportional to the charge, the effects developed in Section *4 The Action of Matter: Motion and Relativity* can be treated as changes to the effective force.

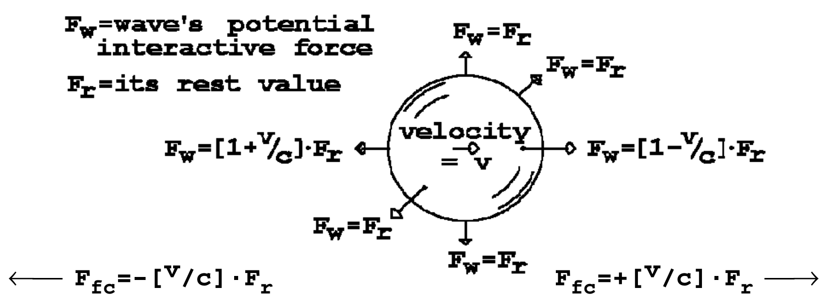

Figure 5-4
The Propagated Wave from the Source Center at Velocity v

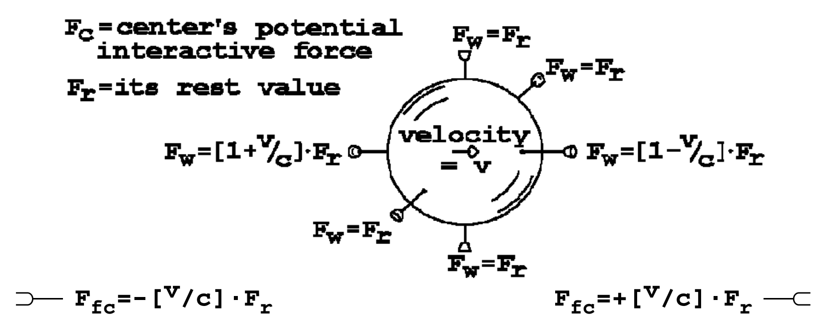

Figure 5-5
The Encountered Center's Oscillation at Velocity v

In motion as the currents I_1 and I_2 the centers exhibit cylindrical symmetry around their direction of motion so that a two dimensional analysis will suffice for the following determination of the actual force effect in any particular direction.

Figure 5-6, below, illustrates the difference between conditions at rest and at velocity. At rest the centers' oscillation and waves have the same force effect in all directions. At velocity the force effect depends upon the angle of view relative to the direction of the velocity, angle θ in the figure.

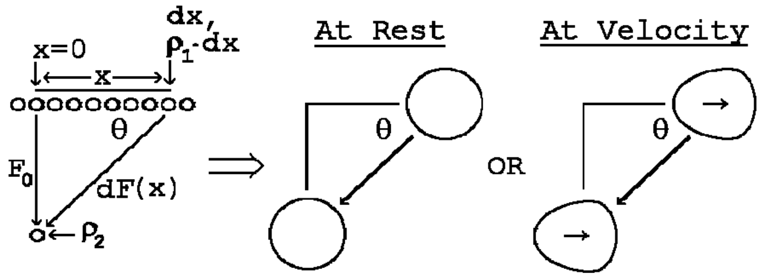

Figure 5-6
The Centers of Figure 5-2 Enlarged

For F_{fc}, the "force component", the analysis of the effect of the "angle of view", θ, is simple. As shown in Figure 5-7, below, its magnitude in any direction is equal to the cosine of the angle between that direction and the pure forward direction times $[^V/c]\bullet F_r$. That relationship applies to both the F_{fc} of the wave and of the center (the point of view of Figure 5-4 and Figure 5-5, above).

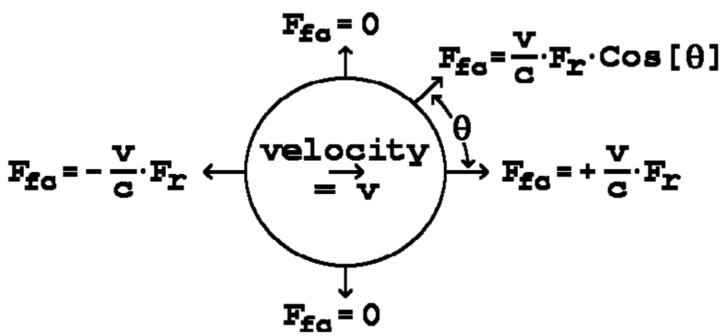

Figure 5-7
The "Force component" Resultant When the Center is at Constant Velocity v

The treatment for the variation of the effect with the angle of view, θ, being essentially the same for both the wave and the center, is also true for the forward wave propagation at $c'=c-v$ producing a reduction of the forward force effect by $[1-^V/c]$.

For the wave, for which the four two-dimensional components (using the cylindrical symmetry of the situation) are per Figure 5-4, the situation is not so simple as for the F_{fc}. If the velocity were zero then the wave resultant would be F_r in all directions and the model of it would be a circle as in Figure 5-8, below. In any non-orthogonal direction the force is obtained from the law of Pythagoras; the force is the hypotenuse and the other two sides are its projection on the x- and y-axes.

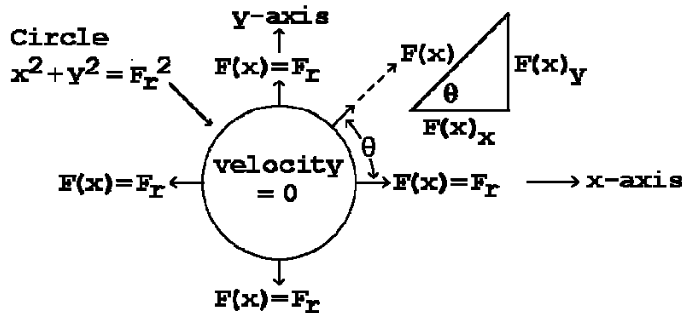

Figure 5-8
The Wave Resultant When the Center is at Rest

In the above figure, the center being at rest and its force effect being the same in all directions, $F(x)$ is always equal to F_r regardless of θ. However, when the center is in motion the situation is analogous but modified. With the center at velocity v, the circle must be modified into the combination of two ellipses, one for the forward direction and one for the rearward as in Figures 5-9 and 5-10

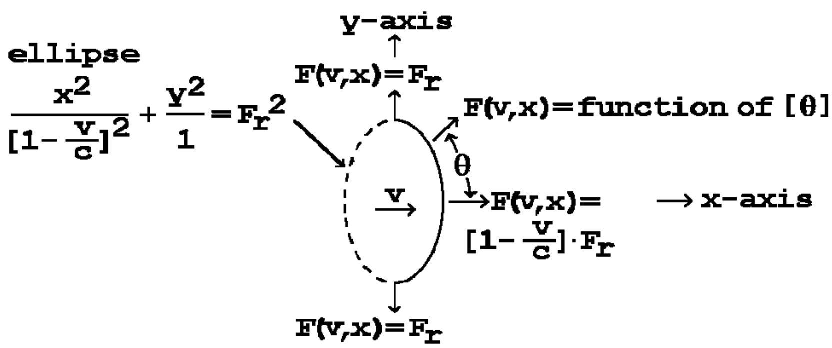

Figure 5-9
The Wave Resultant in the Forward Direction When the Center is at Velocity v

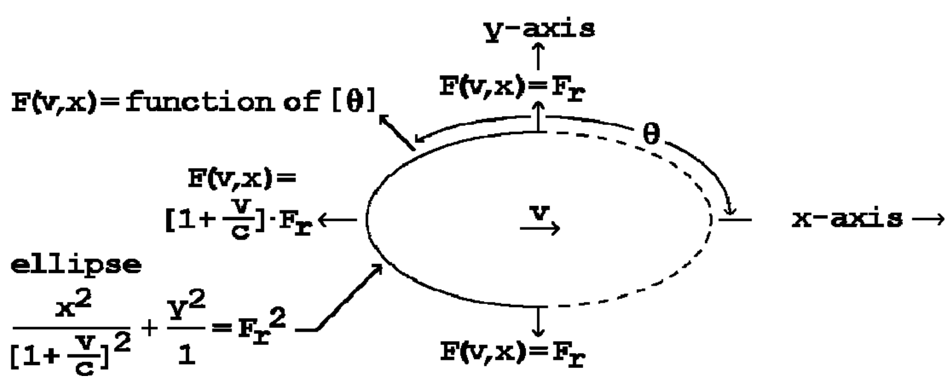

Figure 5-10
The Wave Resultant in the Rearward Direction When the Center is at Velocity v

The equations of these two ellipses as given in the above figures can be generalized as

(5-21) $$\frac{x^2}{W^2} + y^2 = Fr^2$$

where: $W = 1 - {}^{v}/_{c}$ for $+90° \geqq \theta \geqq -90°$
and
$W = 1 + {}^{v}/_{c}$ for $+90° \leqq \theta \leqq +270°$

Changing equation 5-21 from its rectangular coordinates (x, y) to polar coordinates in the variables (R, θ)

(5-22) $$\frac{R^2 \cdot Cos^2(\theta)}{W^2} + R^2 \cdot Sin^2(\theta) = Fr^2$$

is obtained, and solving for the radius, R, the result is

(5-23) $$R = F_r \cdot \left[\frac{Cos^2\theta}{W^2} + Sin^2\theta \right]^{-\frac{1}{2}}$$

Using equation 5-23 to express $F(v,x)$, as defined in Figures 5-9 and 5-10, in terms of the direction angle, θ,

(5-24) $$F(v,x) = F_r \cdot \left[\frac{Cos^2\theta}{W^2} + Sin^2\theta \right]^{-\frac{1}{2}}$$

where: $W = 1 - {}^{v}/_{c}$ for $+90° \geqq \theta \geqq -90°$
and
$W = 1 + {}^{v}/_{c}$ for $+90° \leqq \theta \leqq +270°$

The analysis returns now to the overall situation per Figure 5-11, below, which is the same as the velocity=0 case of Figure 5-3 except that: the charges are now in motion, $F(x)$ is $F(v,x)$, $dF(x)$ is $dF(v,x)$ and angle θ is defined in the figure (and is functionally the same as in the above Figures 5-9 and 5-10).

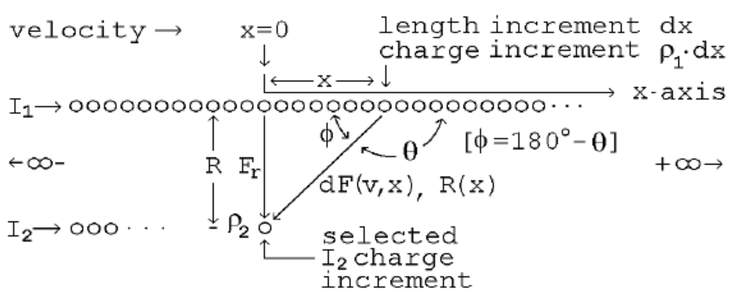

Figure 5-11

The following trigonometric relationships should be noted.

(5-25) $Cos(180°-\theta) = -Cos\theta$ $\quad Cos^2(180°-\theta) = Cos^2\theta$

$Cos(-\theta) = Cos\theta$ $\quad Sin^2(180°-\theta) = Sin^2\theta$

The integration performed before, for the case in which the velocity was zero, was of equation 5-14, first line of which is repeated below.

(5-14) $$\uparrow F_E = \int_{-\infty}^{0} \uparrow dF(x) + \int_{0}^{+\infty} \uparrow dF(x)$$

CASES 1,2 AND 5

The Magnetic Force (The Charges In Motion)

In that expression *FE* is identical to *FT* because the velocity is zero so that $FM = 0$. Now, to deal with the charges in motion and non-zero velocity a new function, $f(v,x)$, is now defined:

$$(5\text{-}26) \qquad f(v,x) = \frac{dF(v,x)}{dF(x)}$$

so that

$$(5\text{-}27) \qquad dF(v,x) = f(v,x) \cdot dF(x)$$

and this function will be integrated in the expression of equation *5-14* by substituting $dF(v,x)$ per equation *5-27* for $dF(x)$. The result will be *FT*, the total force at velocity *v*, rather than *FE*, the static case force.

To proceed, from the definition of $f(v,x)$ per equation *5-26*:

$$(5\text{-}28) \qquad f(v,x) = \qquad\qquad [\text{Cases } 1,\ 2,\ 5]$$

$$= \left[\frac{\begin{matrix}\text{Wave Resultant}\\ \text{in direction } \theta\\ \text{at velocity v}\end{matrix}}{\begin{matrix}\text{Wave Resultant}\\ \text{in direction } \theta\\ \text{at v=0}\end{matrix}}\right] \cdot \left[\frac{\begin{matrix}\text{Center Resultant}\\ \text{in direction}\\ [180°-\theta] \text{ at v}\end{matrix}}{\begin{matrix}\text{Center Resultant}\\ \text{in direction}\\ [180°-\theta] \text{ at v=0}\end{matrix}}\right] + \left[\begin{matrix}F_{fc} \text{ Wve}\\ \text{toward}\\ \theta\\ \text{at v}\end{matrix}\right] - \left[\begin{matrix}F_{fc} \text{ Ctr}\\ \text{toward}\\ 180°-\theta\\ \text{at v}\end{matrix}\right]^{*}$$

* At zero velocity there is no F_{fc} at all.

$$= \frac{\left[\dfrac{\text{Cos}^2\theta}{A^2} + \text{Sin}^2\theta\right]^{-½}}{1} \cdot \frac{\left[\dfrac{\text{Cos}^2\theta}{B^2} + \text{Sin}^2\theta\right]^{-½}}{1} + \left[\begin{matrix}C \cdot \text{Cos}\,\theta\ - \\ D \cdot \text{Cos}\,\theta\end{matrix}\right] \quad {**}$$

** Per equation 5-26, $f(v,x)$ is a measure of relative effects and does not include F_r.

Equations 5-25 have already been applied, and:

A = wave amplitude function of velocity
= $[1-{}^{v}/c]$ forward and $[1+{}^{v}/c]$ rearward

B = center amplitude function of velocity
= $[1-{}^{v}/c]$ forward and $[1+{}^{v}/c]$ rearward

C = wave F_{fc} function of velocity
= $[+{}^{v}/c]$ forward and $[-{}^{v}/c]$ rearward

D = center F_{fc} function of velocity
= $[+{}^{v}/c]$ forward and $[-{}^{v}/c]$ rearward.

Using equation *5-9* for $R(x)$ and the right triangle geometry of Figure 5-11, equation *5-28* becomes

(5-29) $f(v,x) =$ [Cases 1, 2, 5]

$$= \left[\frac{x^2/R(x)^2}{A^2} + \frac{R^2}{R(x)^2}\right]^{-½} \cdot \left[\frac{x^2/R(x)^2}{B^2} + \frac{R^2}{R(x)^2}\right]^{-½} + (C + D)\cdot\frac{x}{R(x)}$$

$$= \frac{A\cdot B\cdot(x^2 + R^2)}{[x^4 + (A^2 + B^2)\cdot R^2\cdot x^2 + A^2\cdot B^2\cdot R^4]^{½}} + \frac{(C + D)\cdot x}{(x^2 + R^2)^{½}}$$

values of A, B, C, and D for which are given in the following Figure 5-12 for Cases *1*, *2* and *5*.

Referring back to equation *5-13*, which separates the entire range to be calculated into two ranges, $-\infty$ to 0, $[<0]$, and 0 to $+\infty$, $[>0]$, the Range column in the Figure 5-12 refers to those two ranges, the two ranges integrated separately because of the different values of *A*, *B*, *C* and *D* in the two ranges per the figure.

Case		Range	A	B	C	D
1	→	<0	$[1-{}^v/c]$	$[1+{}^v/c]$	$+{}^v/c$	$-{}^v/c$
	→	>0	$[1+{}^v/c]$	$[1-{}^v/c]$	$-{}^v/c$	$+{}^v/c$
2	→	<0	$[1-{}^v/c]$	$[1-{}^v/c]$	$+{}^v/c$	$+{}^v/c$
	←	>0	$[1+{}^v/c]$	$[1+{}^v/c]$	$-{}^v/c$	$-{}^v/c$
5	→	<0	$[1-{}^v/c]$	1	$+{}^v/c$	0
	·	>0	$[1+{}^v/c]$	1	$-{}^v/c$	0

Figure 5-12

See Appendix D, *Integration Details for Magnetic Effect Calculations, Part 2*.

The expression to be integrated now is

(5-30)
$$\uparrow F_T = \int_{-\infty}^{0} \uparrow dF(v,x) + \int_{0}^{+\infty} \uparrow dF(v,x)$$

$$= \int_{-\infty}^{0} \uparrow f(v,x)\cdot dF(x) + \int_{0}^{+\infty} \uparrow f(v,x)\cdot dF(x)$$

$$= \int_{-\infty}^{0} \left[\left[\frac{A\cdot B\cdot(x^2 + R^2)}{[x^4 + (A^2 + B^2)\cdot R^2\cdot x^2 + A^2\cdot B^2\cdot R^4]^{½}} + \cdots\right.\right.$$

$$\left.\left.\cdots + \frac{(C + D)\cdot x}{(x^2 + R^2)^{½}}\right]\cdot\left[F_r\cdot\frac{R^3}{[x^2 + R^2]^{1½}}\right]\right]\cdot dx + \cdots$$

$$\cdots + \int_{0}^{+\infty}\left[\begin{array}{c}\text{The same above entire}\\ \text{expression a second}\\ \text{time}\end{array}\right]\cdot dx$$

The integration and evaluation are at Appendix D, *Integration Details for Magnetic Effect Calculations*.

The result of that integration is for each of the 2 ranges

(5-31) $\uparrow F_T = R\cdot F_r\cdot[A\cdot B + C + D]_{>0} + R\cdot F_r\cdot[A\cdot B + C + D]_{<0}$
$= 2\cdot R\cdot F_r\cdot[A\cdot B + C + D]$

which is the result from the static case multiplied in each range by an expression that is the effect of velocity on the centers and their propagated waves. Per equation *5-20* the static force per equation *5-14* must now be subtracted from the new total force, F_T at velocity v per equation *5-31*, to obtain the net magnetic force, F_M.

As equation *5-12* the horizontal forces net to zero.

(5-32) $\vec{F_T} = 0$

The final step in the calculation is to evaluate equation *5-31* for each of cases 1, 2 and 5 by inserting the values of A, B, C and D from the above Figure 5-12, and then determining F_M from the above two equations. The results are tabulated in Figure 5-13.

Case	Range	A·B+C+D
1 → →	<0	$[1+v/c]\cdot[1-v/c] - v/c + v/c = [1-v^2/c^2]$
	>0	$[1+v/c]\cdot[1-v/c] - v/c + v/c = [1-v^2/c^2]$
		$\text{Sum} = 2\cdot[1-v^2/c^2]$
		$\uparrow F_T = 2\cdot R\cdot F_r\cdot[1-v^2/c^2]$
		$\uparrow F_M = F_T - F_E$
		$= F_T - 2\cdot R\cdot F_r$
		$= -2\cdot R\cdot F_r\cdot[v^2/c^2]$
		(attraction)
2 → ←	<0	$[1-v/c]\cdot[1-v/c] + v/c + v/c = [1+v^2/c^2]$
	>0	$[1+v/c]\cdot[1+v/c] - v/c - v/c = [1+v^2/c^2]$
		$\text{Sum} = 2\cdot[1+v^2/c^2]$
		$\uparrow F_T = 2\cdot R\cdot F_r\cdot[1+v^2/c^2]$
		$\uparrow F_M = F_T - F_E$
		$= F_T - 2\cdot R\cdot F_r$
		$= +2\cdot R\cdot F_r\cdot[v^2/c^2]$
		(repulsion)
5 → 0	<0	$[1-v/c]\cdot[1] + v/c + 0 = [1]$
	>0	$[1+v/c]\cdot[1] - v/c - 0 = [1]$
		$\text{Sum} = [2]$
		$\uparrow F_T = 2\cdot R\cdot F_r$
		$\uparrow F_M = F_T - F_E$
		$= F_T - 2\cdot R\cdot F_r$
		$= 0$
		(no effect)

Figure 5-13

The above results agree exactly in direction with the force, F_M, for the three cases: 1, 2, and 5 of Figure 5-1. They agree exactly in magnitude with the force, F_M, per the earlier derivation from traditional 20th Century physics that the ratio of the magnetic force to the electrostatic force is $[v^2/c^2]$, equation *5-19*. Here, however, the magnetic effect is derived from the characteristics and behavior of *Spherical-Centers-of-Oscillation*. As stated earlier, magnetic field is merely the effect of changes in the electrostatic field effect due to changes in the oscillations of the centers and in their propagated waves caused by the centers being in motion rather than at rest.

CASES 3 AND 4

Cases 3 & 4 treat the two currents perpendicular to each other. The magnetic effect between perpendicular currents comes about because each of the two perpendicular currents has a component that is parallel to a component of the other. To derive the force of interaction between two perpendicular currents from the already obtained forces between parallel currents the procedure is as follows (See Figure 5-14 below).

Step (1) - Each of the two orthogonal currents, I_1 and I_2, is resolved into two components, one to the left and one to the right. Thus, I_1 is the resultant of I_{1L} and I_{1R} and similarly for I_2.

(5-32)
$$I_{1R} = I_{1L} = \tfrac{1}{2}\cdot\sqrt{2}\cdot I_1 \qquad I_{1L} \text{ attracts } I_{2R}$$
$$I_{2R} = I_{2L} = \tfrac{1}{2}\cdot\sqrt{2}\cdot I_2 \qquad I_{1R} \text{ repels } I_{2L}$$

Step (2) - I_{2R} is attracted by I_{1L} (Case 1) in the amount F_A using the form of equation *5-3* [F_M per unit length].

(5-33)
$$F_A = \frac{\mu}{2\cdot\pi}\cdot\frac{I_{1L}\cdot I_{2R}}{R_c} = \frac{\mu}{2\cdot\pi}\cdot\frac{\left[\frac{1}{2}\sqrt{2}\cdot I_1\right]\cdot\left[\frac{1}{2}\sqrt{2}\cdot I_2\right]}{R_c} = \frac{\mu}{2\cdot\pi}\cdot\frac{I_1\cdot I_2}{2\cdot R_c}$$

Similarly, I_{2L} is attracted by I_{1R} in the amount F_B.

(5-34)
$$F_B = \frac{\mu}{2\cdot\pi}\cdot\frac{I_{1R}\cdot I_{2L}}{R_c} = \frac{\mu}{2\cdot\pi}\cdot\frac{\left[\frac{1}{2}\sqrt{2}\cdot I_1\right]\cdot\left[\frac{1}{2}\sqrt{2}\cdot I_2\right]}{R_c} = \frac{\mu}{2\cdot\pi}\cdot\frac{I_1\cdot I_2}{2\cdot R_c}$$

These two forces are depicted in Figure 5-15, below

Step (3) - The resultant of the two forces, F_A and F_B, is F_m, the net magnetic force, and its magnitude per equation 5-35, next page, and its direction per Figure 5-15 are correct for Case 3.

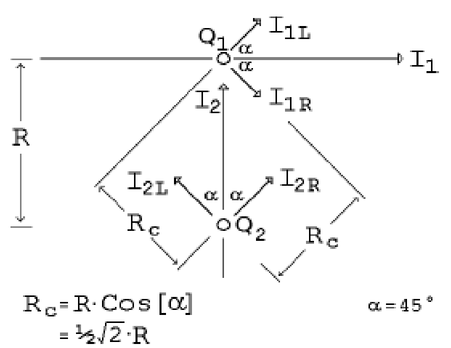

Figure 5-14

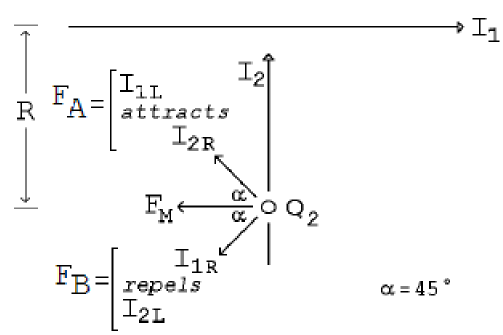

Figure 5-15

(5-35)
$$F_M = \sqrt{2}\cdot F_A = \sqrt{2}\cdot F_B = \sqrt{2}\cdot\frac{\mu}{2\cdot\pi}\cdot\frac{I_1\cdot I_2}{2\cdot R_c} = \frac{\mu}{2\cdot\pi}\cdot\frac{I_1\cdot I_2}{R}$$

[From Figure 5-14 $R_c = \frac{1}{2}\cdot\sqrt{2}\cdot R$].

If the direction of I_2 is reversed Case 4 is obtained and a review of the above analysis will show that the resulting magnitude of F_M is the same as for Case 3 while the direction of F_M is opposite to that of Case 3.

Thus the magnetic force in Cases 3 and 4 is demonstrated, which completes the derivation of magnetic field from *Spherical-Centers-of-Oscillation* considerations. As with Coulomb's Law and electrostatics, Ampere's Law and magnetostatics are now moved from the realm of empirical results to derived results, results derived from the origin of the universe and its implications.

The Electro-Magnetic Action (Varying Charge Velocity)

When the charges, the *Spherical-Centers-of-Oscillation*, are in motion at various speeds in various directions, they always exhibit the electrostatic Coulomb behavior at each "still" instant of their motion. And, when they are so in motion they always exhibit the magnetic Ampere behavior at each "momentary constant velocity" instant of their motion.

When the motion involves changing speed and / or changing direction the effect is a "stream" of the individual states exhibited at each instant of the motion, each successive state being in effect an imprint on the *Propagated Outward Flow*, of Figure 4-3 "*The Center's Propagation as Observed from At-Rest"*.

The "stream" is analogous to a motion picture projection of successive frames of a "moving picture" each frame slightly different from its predecessor. But, whereas the motion picture presents discrete "frames" the "stream" of states from electric charges is smooth and continuous and radially outward in all directions.

In electronic communications information is carried as variations, modulation, in the frequency or amplitude of a flat, smooth unchanging oscillation, the carrier wave. In the case of the stream of the individual states exhibited at each instant of the motion of an electric charge the "carrier wave" is the *Propagated Outward Flow* and the "information carried" modulation of the carrier is the succession of the various forms of the center's propagations. The variations in the electric charge's *Propagated Outward Flow* are a modulation of what its *Propagated Outward Flow* would be if the electric charge were not in motion.

That stream of flow modulated by a succession of the various states of motion of the source electric charges, or rather the actual modulation itself, appears to us as what we term Electro-Magnetic Waves: light, radio, television, and various communications.