CHAPTER TWENTY -SIX

An Examination of the Faraday Homopolar Generator

Defining Magnetic Induction

Michael Faraday conducted several experiments that demonstrated a current could be induced to flow in a wire by one of three methods. Move the wire relative to a magnet, move the magnet relative to the wire, or change the strength of the magnetic field. This discovery led to Faraday's law of induction and contributes to Maxwell's laws of electromagnetism. In addition to these experiments he also conducted a less heralded experiment where he affixed a copper disc atop a cylindrical magnet and rotated the ensemble. From this apparatus he was able to generate a current at the edge of the copper disc. This ensemble was dubbed the the Faraday Disc. A single spinning round conductor placed between two magnets performs identically and is called the homopolar generator, or unipolar dynamo, or an acyclic generator.

The results of this experiment have never been satisfactorily explained because it appears to be at odds with his more famous law of induction. In the classical inductive process, apart from the creation of a current, it is the relative motion of the magnet and the conductor that are important. It doesn't matter which moves as long as they move relative to each other. Such is not the case with the homopolar generator. A generated current is dependent solely upon rotation of the conductor disk. It makes no difference if the magnet is spun or not.

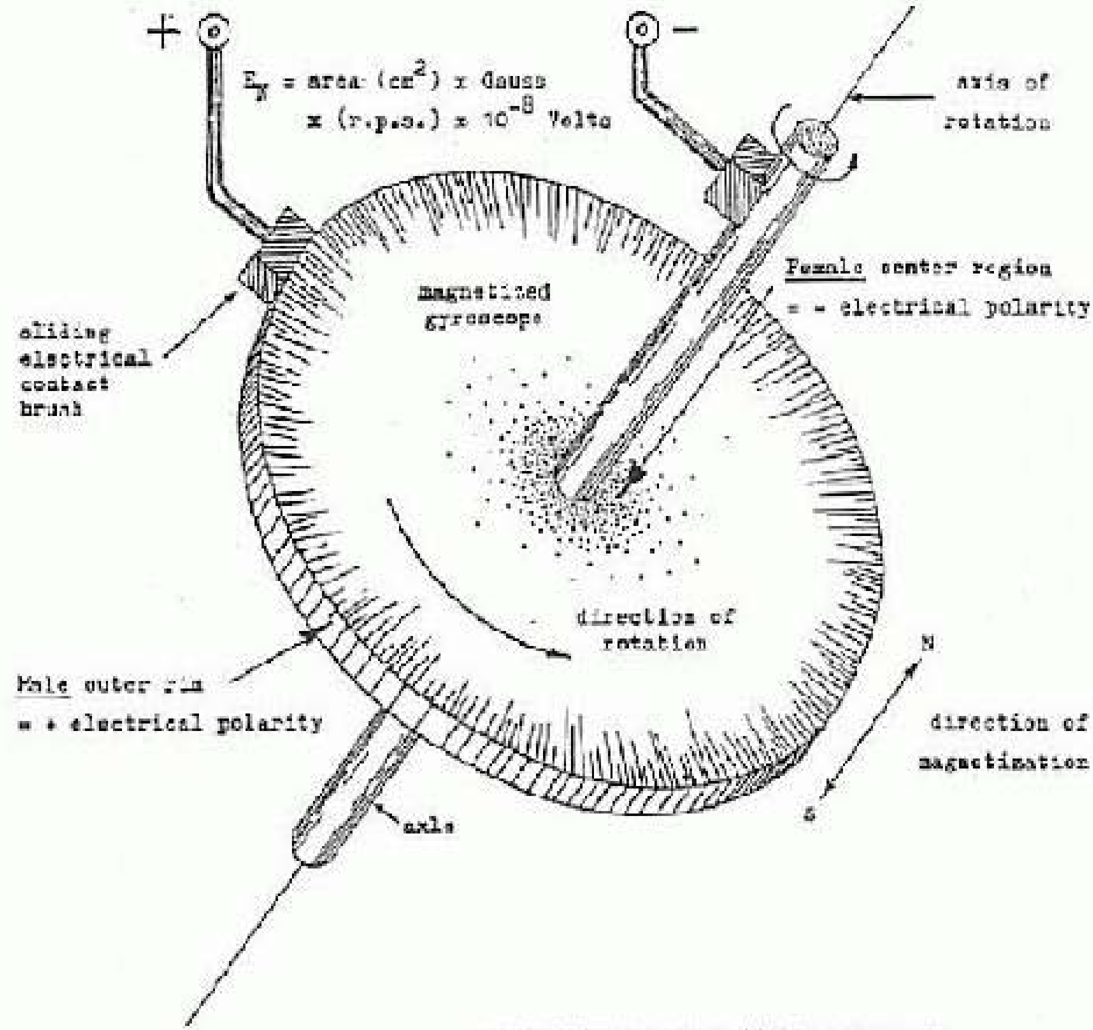
In addition to the production of this seemingly non-inductive current, if one draws this current away from the disc then a back torque is produced. The existence of the back torque seems to violate Newton's third law in that there is no apparent equal and opposite reaction. The creation of back torque is normal in a typical DC generator.

Figure 1 was chosen as an illustration of the homopolar generator because it emphasizes the fact that the generator is simply a rudimentary magnetized gyroscope, a fact that will have great significance as we explain the dynamics of a generator in greater detail.

Figure (1)

Rotation of a Magnetized Gyroscope

The "N" Machine

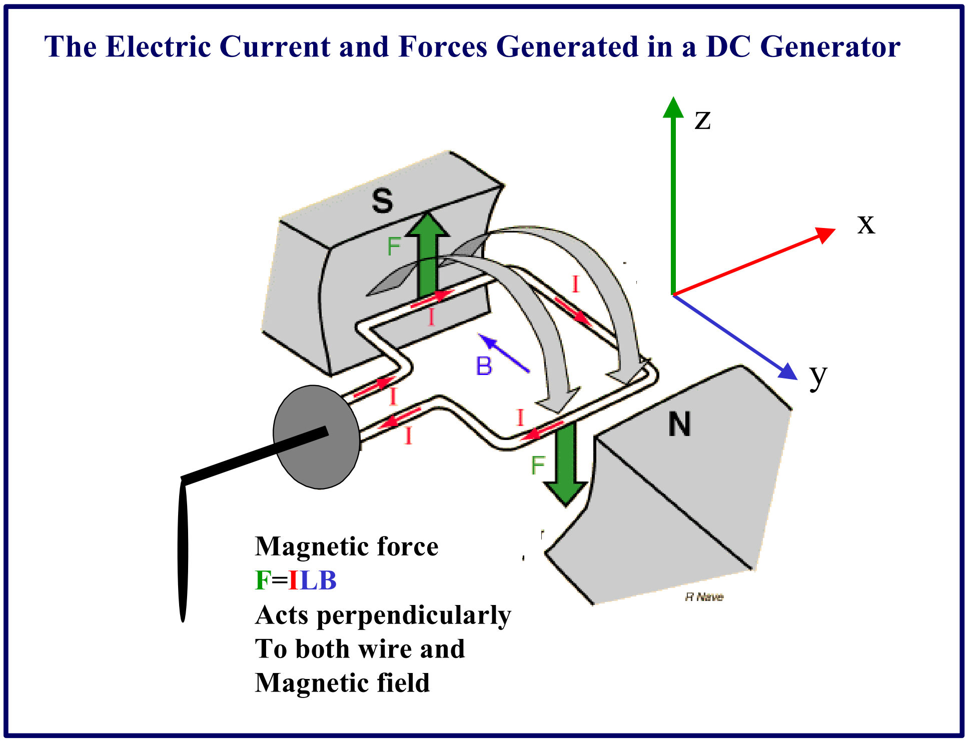


polarities reverse if direction of magnetization or sense of rotation is reversed

Extraction of the positive and negative poles of electricity from the energy field of space

Let us first review the construction and performance of a typical DC generator. As a broad oversimplification , a motor and generator are pretty much the same machine, however they perform opposite functions. In a motor you supply an electrical current to supply torque. In a generator you supply the necessary torque so as to generate an electrical current. Consider Figure 26a. (Illustrations adapted from Nave's Hyperphysics)

Figure 26a

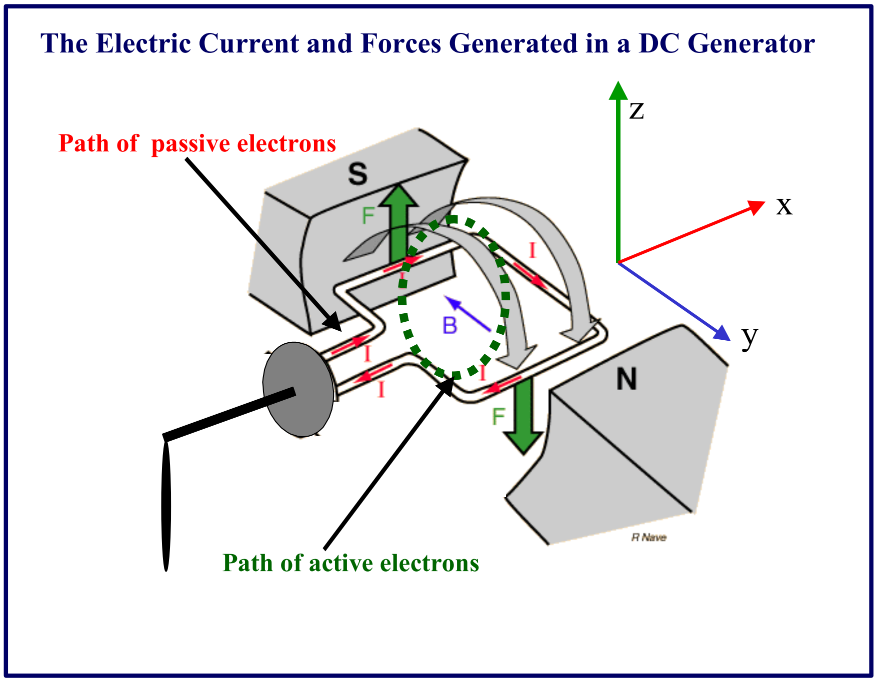


A conducting loop is connected to a hand crank. A magnetic field is applied to the loop conductor via two bar magnets . As the hand crank is turned in the zy plane a current is created in the current loop in the xy plane. This is an example of Faraday's magnetic induction. One critical aspect of such current generation, frequently ignored by scientists, is that not only are the electrons executing circular motion in the xy plane but in addition to this they are also being forced to orbit in the zy plane as well. Therefore, by definition, the electrons that form the current are precessing. *Indeed, the GFT posits that electric induction can occur if and only if electron precession is executed*.

Creating a Homopolar Generator From a DC Motor

Refer to Figures 26b and 26c. This figure illustrates the forces and currents generated in a typical DC generator particularly those in the zy plane.

Figure 26b



The Electric Current and Forces Generated in a DC Generator
Path of passive electrons
S
F
I
B
N
z
x
y
Path of active electrons
R Nave

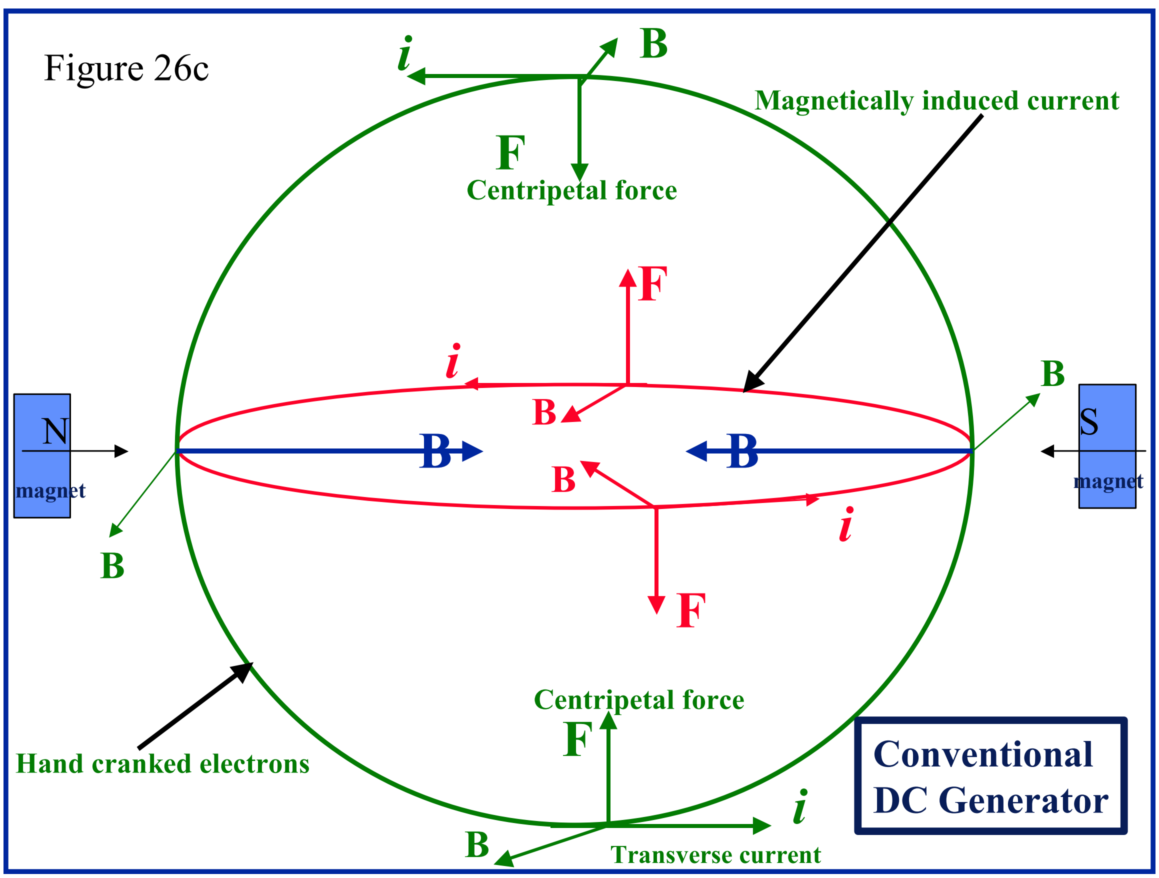


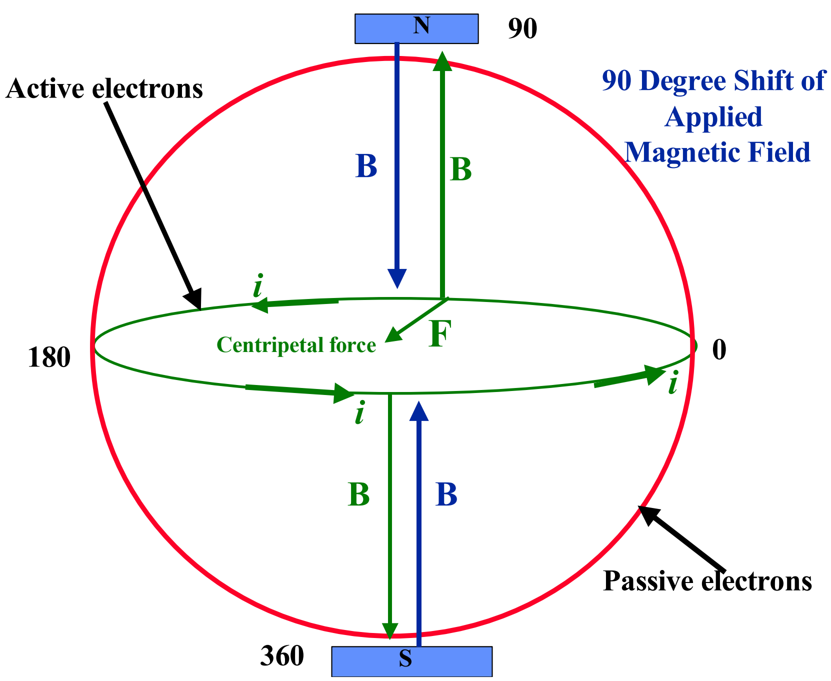
Figure 26c
i
B
Magnetically induced current
F
Centripetal force
F
i
B
B
B
B
N
magnet
S
magnet
B
i
F
B
Hand cranked electrons
Centripetal force
F
i
B
Transverse current
Conventional DC Generator

Referring to Figure 26c imagine that the hand crank projects out of the page and attaches to the red conductor loop. For the moment disregard any effects of the magnets. As the crank is turned the electrons in the loop must also turn, tracing out the virtual green loop These electrons, which we will name the active electrons, must follow (in space) the green loop which is defined in the zy plane. Again this movement of electrons is completely divorced from any effects of the magnet and will occur as long as the crank is turned. As with any particles undergoing circular motion the active electrons in the virtual green loop it will have exerted upon them an inwardly directed centripetal force. In this case the centripetal force coincides with the electric force created by the moving charges. Given the constraints of a particle undergoing circular motion these particles will also possess a transverse velocity thus forming a transverse current. Since these active electrons are moving charged particles they will obligatorily generate a magnetic field, the B field, that is parallel to the crank and projects out of the page.

The presence of the magnets, however causes magnetic induction of a current in the conductor loop. A current consisting of, what we will name, passive electrons. These passive electrons follow the path of the red loop which is defined in the xy plane. These passive electrons also execute simple circular motion therefore, in both the zy and xy current loops the currents are transverse currents. Juxtaposition of these two transverse currents obligatorily sets the electrons into precession. If we were to ride along with any of the active electrons we would find that in the zy current loop the B field is always at right angles to the B field.

Referring to Figure 26c suppose we were to rotate the set of magnets 90 degrees so that the magnets projects out of either side of the page and are parallel with the crank handle. . Refer to Figure 26d (It has been drawn so that the magnets stay within the plane of the page)

Figure 26d

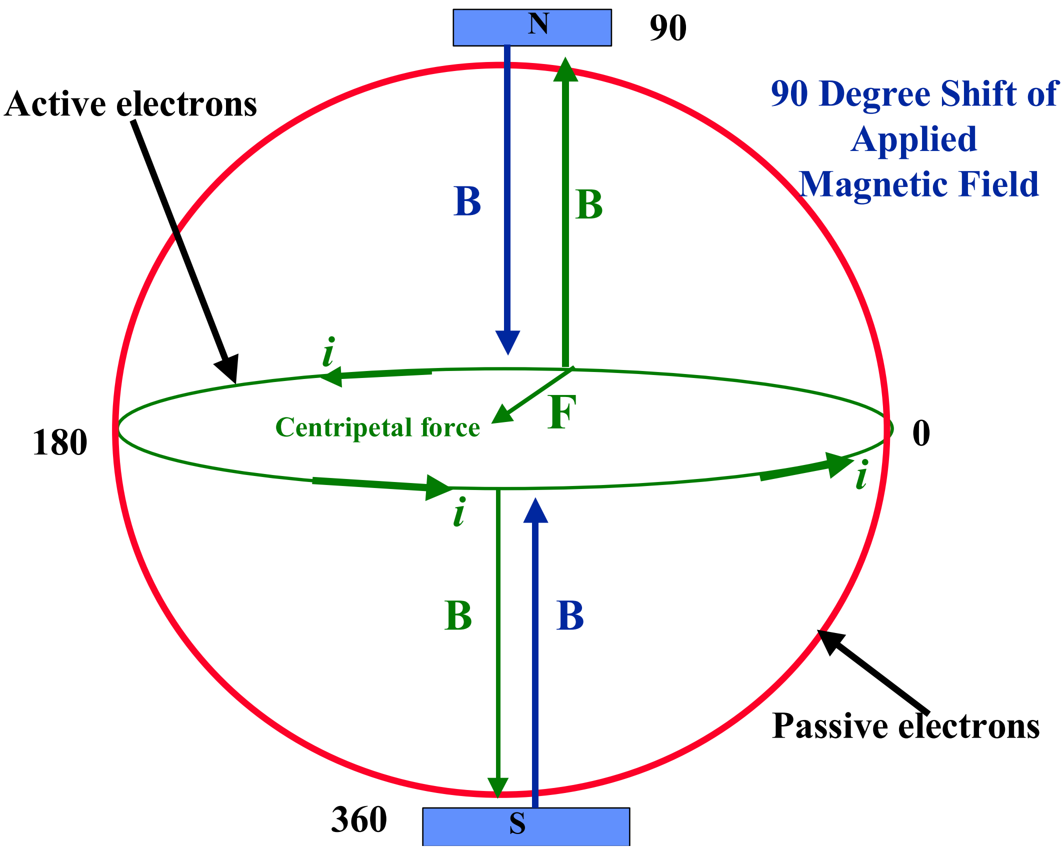


If we refer again to figure 26a we see that even though the magnets have shifted 90 degrees the average position of the passive electrons to the magnetic field has not been altered. This is because those passive electrons that were once parallel are now perpendicular to the field and vice a versa. This arrangement does not hinder the magnetic induction of current. Also note that the precession of the electrons is also preserved. Again, electric induction can occur if and only if electron precession is executed. No precession no induction.

Up to this point the green conduction loop has been presented as a type of abstraction since it, physically, does not exist. It is important to emphasize that even though the green conductor loop is an abstraction the movement of the active electrons, and their concomitant current, is not. This current is every bit as real as the induced current in the physically real red conductor loop. Suppose we now replace the green loop abstraction with a real physical conduction loop. Indeed, we can add several loops, concentrically placed, such that we now form a conduction disc. In so doing we have just created a crude version of a homopolar generator around which spins a conductor loop (red). Note however, that the current in this crude homopolar generator is still a transverse current. The experimental evidence says that the that the current of a homopolar generator is a radially directed current and that the electric force it generates is transverse. If we were to ride one of the active electrons in the conductor disc this is exactly the current configuration one would see in the passive electrons of the red conduction loop. That is to say the currents and electric forces generated by both disc (green) and original conductor loop(red) are all mutually orthogonal. The current of the red loop flows at a right angle to the current of the conductor disc. The electric force generated by the conductor loop forms at a right angle to the electric force generated by the conductor disc. Again, in this two piece ensemble of loop and disc the electrons, and their concomitant electric forces are in a state of precession. The task now becomes to combine the active and passive electrons, or loop and disc, such that the radial current and transverse electric force is manifest within the disc, thus forming a true homopolar generator.

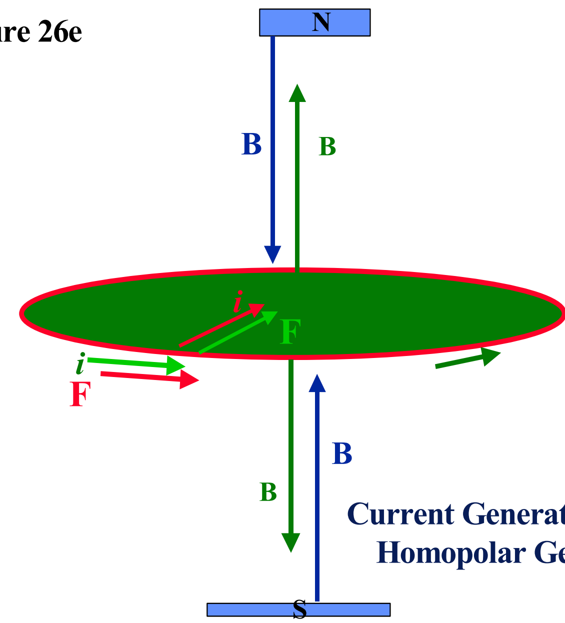
We can physically incorporate the passive red current loop into the, now physically present, conductor disc by simply rotating the red disc 90 degrees so that it is now parallel with and incorporated into the conductor disc. Unfortunately, this 90 degree shift destroys the orthogonal relationship that previously existed between the active and passive electrons. This, in effect ostensibly nullifies any precession of the electrons. However, this does not mean that it alters the behavior of the passive electrons. It is obvious that all the electrons must act under the same set of forces and conditions and thus all the electrons must behave identically. Thus all of the electrons must still exhibit a transverse current and a radially directed electric force. Our task now is discover those conditions which will cause the electrons to precess and thus preserve magnetic induction.

Figure 26d



I n Figure 26d note that the active electrons produce their own B fields whose polarity is identical to that of the applied B field. The disc, possessing two opposite magnetic poles, by definition, possesses a magnetic dipole. This magnetic dipole is aligned parallel to the applied magnetic field of the magnets. A magnetic dipole when subjected to an applied magnetic field will precess about that field. Since the disc is restrained from physically precessing its electrons are then forced to do so. It is this forced precession which generates the radially directed current. Indeed, since the electrons are in a state of precession there will be both a transverse and a radial current and a transverse and a radial electric force. Juxtaposition of the current and force vectors have the effect of accelerating the electrons which accounts for the ability of the homopolar generator to produce large currents with a relatively small voltage.

Figure 26e



Current Generation in the Homopolar Generator

Back Torque

The homopolar generator is an excellent device for generating direct current with a relatively small voltage. However once current is drawn from the device it exhibits a severe back torque or armature reaction thus making it a very inefficient machine for practical use. Thomas Valone states in his book The Homopolar Handbook, "…others have sought to explain the Number One Homopolar Mystery: the torque is created within the conducting magnet without an apparent equal and opposite reaction!"

The GFT version of the homopolar generator very simply clarifies this ostensible conundrum. Refer to Figure 26e. This illustration demonstrates two crucial points. One is that current and electric force are comingled, coaligned, and coincident. The second is that centripetal force and electrical force are indistinguishable. When current is ostensibly drawn from the homopolar generator one also withdraws from it an electrical/centripetal force. Very simply by drawing away current you draw away the ability of the disc to turn thus the manifestation of back torque.

We now ask, just what, exactly, is *Fi*? We know that F must be either the centripetal force or the electric force exerted on wire carrying a current through a magnetic field. Therefore

$$Fi = (ilB)i$$

$$Fi = i^2 lB$$

$$B = \frac{R}{r^2}$$

$$l = r$$

$$Fi = i^2 \frac{R}{r}$$

$$V = iR$$

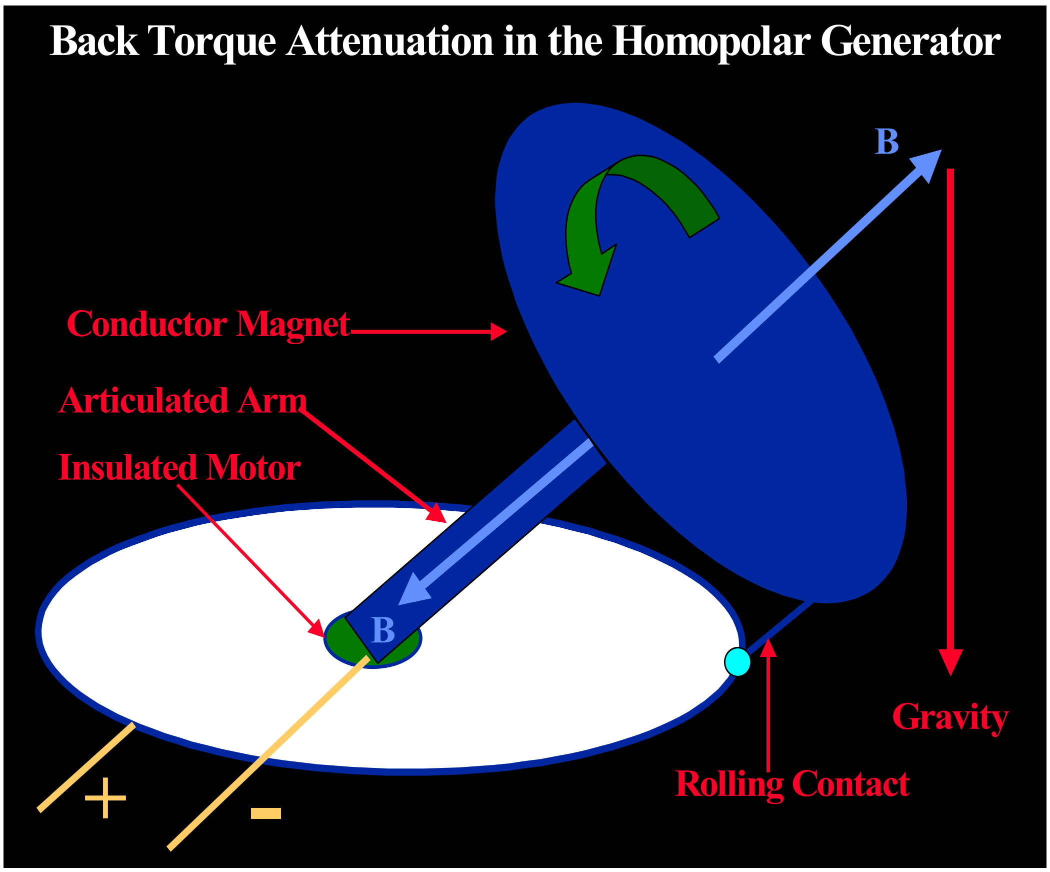
$$R = \frac{V}{i}$$

$$Fi = i^2 \frac{V}{ir} = \frac{Vi}{r} = \frac{Vi}{l}$$

Mathematically we see that *Fi* is actually power per length of wire or loop. Therefore, when current is drawn from the homopolar generator its power is diminished which is manifest as back torque.

Experiments and Practical Application

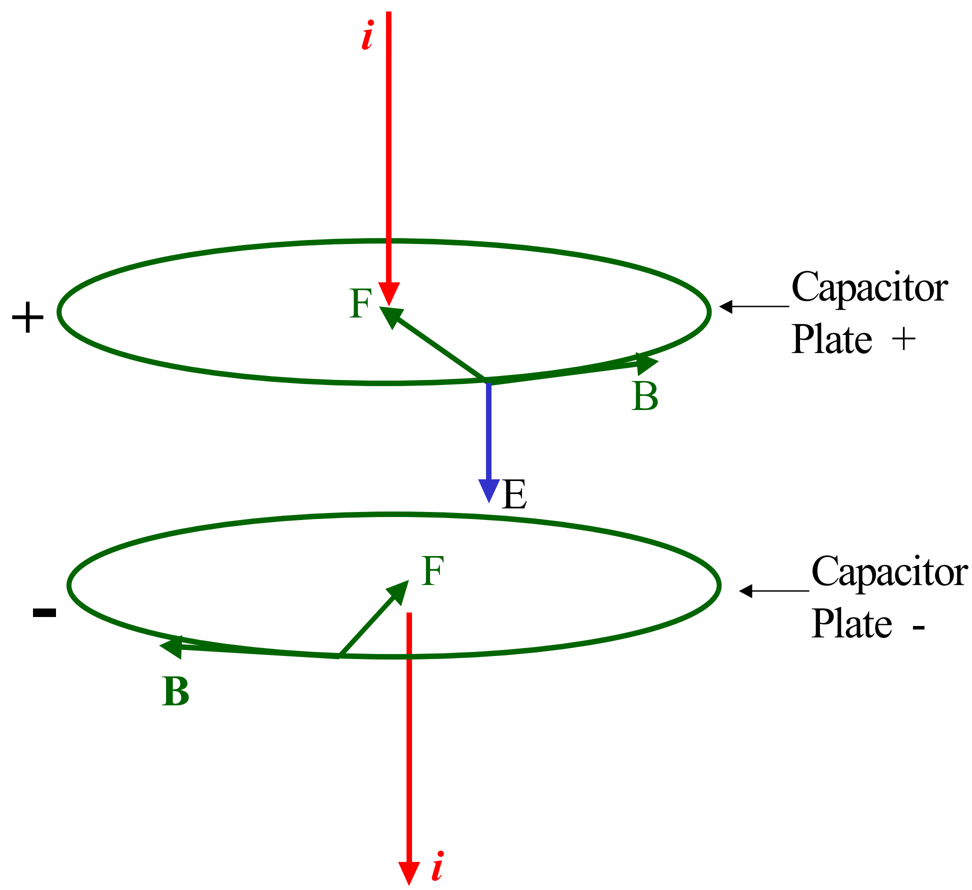
At the outset of this chapter it was stated that Figure 1 was chosen as an appropriate illustration of the homopolar generator being a magnetized gyroscope. It was posited that the electrons in the homopolar generator are forced to precess even as the gyroscope itself is restrained from doing so. As an experiment we should therefore be able to enhance electron precession by allowing the gyroscope itself to precess thus diminishing the effects of the ensuing back torque. See figure 26f.



The Genesis Maxwell's Displacement Current

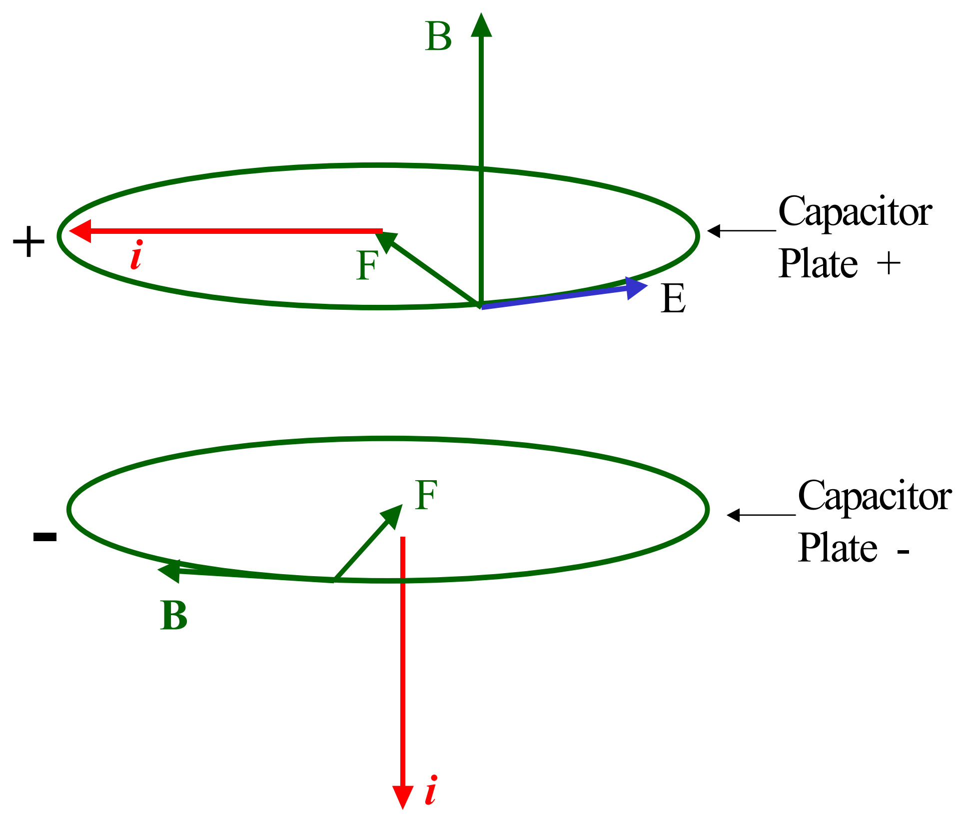
A current can be made to propagate across the gap of a capacitor, in ostensible violation of Ampere's law. Maxwell rectified this with an addendum of his displacement current onto Ampere's law.[See figure 26g.

VECTOR ANAYSIS OF MAXWELL'S CAPACITOR



Note that the depicted vector elements developed for each plate in the capacitor are similar to those developed in the unipolar conductor plate as depicted in figure26e. Imagine the centrifugal force vector as being an axle with all other vectors developed in the capacitor plate being connected to the axle. By turning the axle 90 degrees counter clockwise and allowing the plate to spin we duplicate the conditions of the unipolar generator in figure 26g. Therefore Maxwell's displacement current is the orthogonal equivalent to the transverse current found in the unipolar generator.

AN ACYCLIC GENERATOR OF MAXWELL'S CAPACITOR AT 90 DEGREES



For two dimensions, we state that if a charged particle is simultaneously subjected to two mutually orthogonal forces then a current , an electric field, and a magnetic field will be induced, all mutually orthogonal. This can be expressed mathematically as

$$FxF = \nu\left[\left(qr\right)x\,BxE\right] \qquad \textbf{(2)}$$

where ν is the frequency. Equation 2 indicates that the presence of any two orthogonal forces in a rotating system will evince a current and its accompanying magnetic and electric field. This can be tested experimentally by allowing Maxwell's capacitor to precess mechanically or under the influence of gravity. A current will be induced in the inflow and outflow wires.