Electrical Essay

Electromagnetic Space-Ship

THE USUAL TYPE of powered vehicle requires a material medium upon which the vehicle exerts its thrust or traction. Thus the locomotive pushes back on its track; the propeller-driven airplane pushes back upon the surrounding atmosphere; even the jet-airplane or rocket pushes back on the discharged gases. In this essay is described a means of propulsion which does not require any material medium upon which the propelling thrust is exerted. It will be suitable, therefore, for driving space ships in interplanetary or interstellar journies and I earnestly call it to the attention of promoters and investors who contemplate entering into this virgin field of activity.

The principles upon which the invention of this essay is based, are elementary, widely known, utilized, and proved in every dynamo-electric machine, and universally accepted. Nevertheless, let us review these elementary principles.

1. Force on a Current in a Magnetic Field. A current of i amperes, flowing along a length of l centimeters, and in a perpendicular magnetic field of H gauss, will experience a force or thrust F dynes which will be perpendicular to the current and the magnetic field, and which is given numerically by

$$F=\frac{Hil}{10}$$

The correctness of this formula is verified millions of times daily on the test floors of the plant at which the writer works. In Figure 1, a conductor AB carries current in a magnetic field set up by a permanent magnet with poles N and S. The thrust at right angles is shown by the arrow F. If the conductor AB is not held fast, the conductor AB will be moved by the thrust. In the electric motors manufactured by my company, the conductor AB does move.

2. Reaction of Current on Magnet or Magnetic Field Structure. Corresponding to the thrust F on the current AB of Figure 1, there is an equal and opposite thrust on the poles of the magnet, N, S. This comes about because the current AB produces a magnetic field which links it by a right-hand rule as shown in Figure 2. This magnetic field above the current AB acts on the magnetic pole N with a push shown as $F/2$. The magnetic field below the current is in the opposite direction, but the pole S is also of opposite polarity, so that the push on the pole S is in the same direction as that on N. The total push on N and S is just equal and opposite to the push on the current AB, illustrating a principle attributed to Isaac Newton.

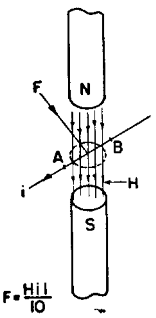

Figure 1

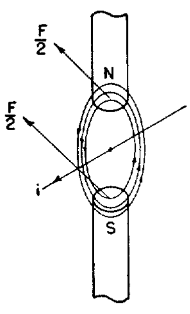

Figure 2

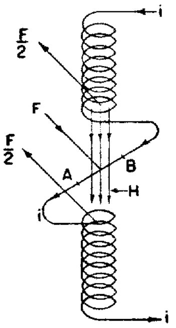

Figure 3

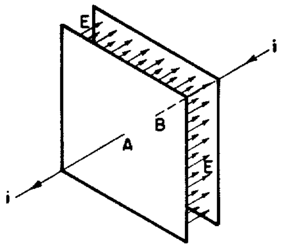

Figure 4

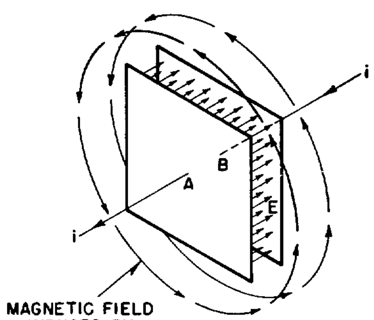

Figure 5

The poles of the stators of the motors which my company manufactures are fastened down very securely so that they will not be moved by this force of reaction of the current on the magnetic field structure.

3. An Electromagnet May Replace the Permanent Magnet. It is well known that a solenoidal coil of wire carrying current produces a magnetic field entirely similar to that of a permanent magnet. This similarity even extends to its also producing a thrust F, on the current AB as is shown in Figure 3. Likewise the current AB through its magnetic field exerts a reaction force on the solenoid coils which is equal and opposite to F.

For convenience and economy we may use the current going through AB for also exciting the electromagnets.

In the machines manufactured by my company, electromagnets very successfully replace permanent magnets.

4. Alternating Current May Replace Direct Current. If in Figure 3, we use alternating current instead of direct current, the magnetic field acting on AB also will be alternating. However, just at the moment the magnetic field reverses, the current AB also reverses. Hence the thrust F will not reverse but always will be in the same direction. Hence even with alternating current the current AB will continue to be pushed in the same direction as in Figure 3. Also, the alternating current field structure will be pushed in the opposite direction, as shown in Figure 3.

The a-c series commutator motors which my company manufactures really do run very well.

5. There Are Displacement Currents. If a high enough frequency is used, then a break in a circuit has very little effect upon the flow of current in the circuit. In Figure

4, the section of the conductor AB has been removed, and replaced by empty space between two large parallel plates. If these plates are a yard square, and a foot apart, then only a few thousand volts will send a thousand amperes of current through the circuit, including the empty space between the plates, if the frequency is a hundred million cycles. This current between the plates is called displacement current, and its density is said to be $\frac{1}{4\pi}\frac{\partial E}{\partial t}$, where E is the electric force in the electric field between the plates. If $\frac{1}{4\pi}\frac{\partial E}{\partial t}$ is integrated or added up over the whole area of the plate, it will just equal the current in the wire. There is then no break in the intensity of the current round the circuit. Just as much current flows in the empty space, as in the wire leading to the plate.

The empty spaces made with vacuum pumps in the research laboratory of the company by which I am employed are very efficient in carrying displacement currents. They heat up hardly at all, even with quite intense displacement currents.

6. *Displacement Currents Are as Good as Any Other.* Clerk Maxwell states that displacement currents produce magnetic fields in exactly the same way and in precisely the same degree as any other currents. In fact that is why electromagnetic waves propagate and give us radio. Hence, as shown in Figure 5, there will be a magnetic field circling the displacement currents. At a radius beyond the plates, the magnetic field produced by the displacement currents is just as large as that produced if the conductor AB replaced the empty space, and carried the same current.

7. *Driving Force for a Space Ship.* Now, to get a driving force for a space ship, all we need to do is to put the magnet system of Figure 3, together with the displacement currents of Figures 4 and 5. Then we get the system shown in Figure 6. Fasten this securely to the body of a space ship, connect the terminals to a source of 100 million cycle power, and off she will go. If we put 1,000 amperes in the space between the plates (which is easy), and 5,000 gauss in the coils, (my company puts more than 10,000 gauss in its field poles) then the force will be

$$\frac{Hil}{10}=\frac{5000\times1000\times30}{10}$$

or 15 million dynes. That is a lot of force, but if it is not enough, we can make the empty space larger, or we could have a battery of these electromagnetic propulsion machines working together. In this last case we could steer by reversing some of the machines. If we reverse all the machines we have regenerative braking!

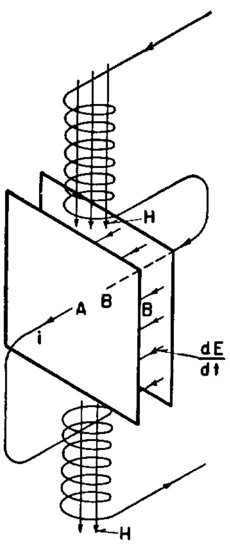

Figure 6

The reader may be puzzled by the force of 15 million dynes on the empty space between the plates in Figure 6 because this space is immaterial. However, this question itself is immaterial to the success of my invention, the space ship. The driving of the ship depends upon the real force coming from the action of the magnetic field of the current i upon the field poles. These poles are just as material as the poles on my company's motors, and a magnetic field will act on them with just as material a force.

By describing this invention in an electrical essay, instead of a regularly submitted technical paper, I avoided the annoying questions and criticisms of reviewers. However, now I am committed to leaving the readers with some questions to answer. Therefore:

1. In principle, is there an unbalanced or net force on the material system of the space ship of the same nature and with magnitude of the same order as that described and estimated in the essay?

2. In principle, can this unbalanced or net force drive the space-ship on its journey?

Author's answers: Question 1. Yes. Question 2. No.

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Answer to Previous Essay—The Black Box

The following is the author's solution to the previously published essay entitled, "The Black Box" (*EE, Jan '49, p 29*).

The black box contains nothing but a mechanically driven switch, (perhaps by a spring motor). The circuit is closed half of the time, and open half of the time, but the interruptions are of a high enough frequency, to make the meters read the steady average value. The current therefore consists of 20-ampere pulses, followed by periods of zero current of equal length. The wattage in the black box is zero because at the time when the current flows, the

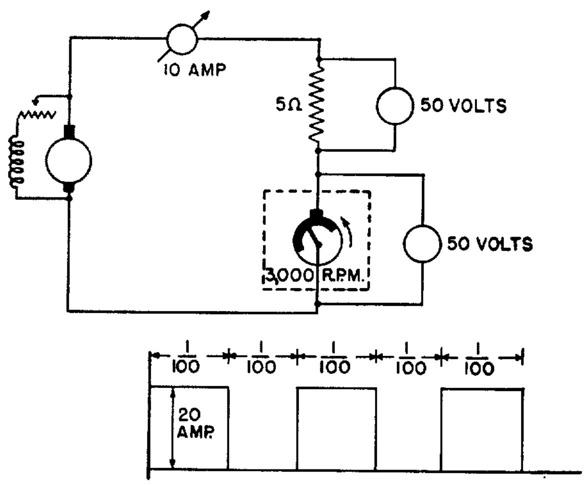

Figure 1

voltage across it is zero, while at the time when the voltage is 100 volts, the current is zero. The average value of the current is 10 amperes, but the rms value is 14.12 amperes, resulting in a power of 1,000 watts in the 5-ohm resistor.

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Electrical Essay

Spark-Gap in Wonderland

"ALICE walked over to a workbench in the laboratory upon which there was some apparatus with an open laboratory notebook beside it. The apparatus consisted of a glass tube whose internal diameter was about four centimeters, containing two rather snugly fitting plane electrodes, clearing the walls by about a millimeter, and separated from each other by two or three centimeters. Wires came up to the tube, and there was a confusion of switches, meters, and gauges. Alice read in the notebook:

With one megohm in series to limit the current I applied 3,000 volts direct current to the spark-gap. No breakdown occurred. On lowering the voltage to about 2,000 volts, the gap suddenly broke down, glowing, with a current of 0.2 milliampere flowing through it. On raising the voltage, the gap is suddenly cleared, giving zero current. This I repeated many times. The gap spacing was 2.7 centimeters and the gas pressure was 0.8 millimeter of mercury.

"Said Humpty-Dumpty who had accompanied her into the laboratory:

'When I want to break down a spark-gap, I always lower the voltage impressed on it, and when I want to clear the gap, I raise the voltage impressed on it.' "

Is it only in Wonderland that spark-gaps such as described exist?

Answer to Previous Essay

The following is the author's answer to his previously published essay, "Electromagnetic Space-Ship" (*EE, Feb '49, pp 145–6*).

The author steps out of his role of inventor and into the role of critic in answering the questions raised in the essay.

The inventor of the electromagnetic space-ship is right in principle in calculating the unbalanced forces on his space-ship except that he does not go far enough. He rightly expects that corresponding to each element of volume dV of his empty space where he has an electric displacement current density, $\frac{1}{4\pi}\frac{\partial \boldsymbol{E}}{\partial t}$ and a magnetic field intensity $\boldsymbol{H}$, there will be an element of unbalanced force $d\boldsymbol{F}_1$ for his material system, given by $d\boldsymbol{F}_1=\left[\boldsymbol{H}\times\frac{1}{4\pi}\frac{\partial \boldsymbol{E}}{\partial t}\right]dV$. However, he overlooks the fact that he also has in his empty space a magnetic displacement current density $\frac{1}{4\pi}\frac{\partial \boldsymbol{H}}{\partial t}$ and an electric field $\boldsymbol{E}$. This electric field $\boldsymbol{E}$ and magnetic displacement current density $\frac{1}{4\pi}\frac{\partial \boldsymbol{H}}{\partial t}$ also, for equally good reason, will give an element of unbalanced force on his material system which is given by the equation $d\boldsymbol{F}_2=\left[\frac{1}{4\pi}\frac{\partial \boldsymbol{H}}{\partial t}\times\boldsymbol{E}\right]dV$.

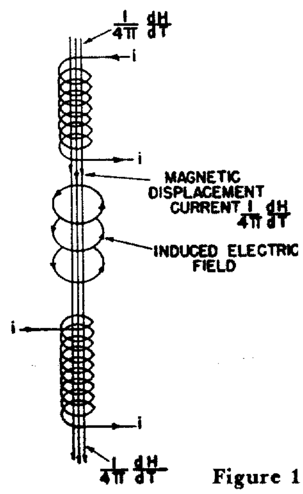

Figure 1

The total unbalanced force on his material system corresponding to each element of volume of his empty space is then, $d\boldsymbol{F}=d\boldsymbol{F}_1+d\boldsymbol{F}_2=\left[\boldsymbol{H}\times\frac{1}{4\pi}\frac{\partial \boldsymbol{E}}{\partial t}\right]dV+\left[\frac{1}{4\pi}\frac{\partial \boldsymbol{H}}{\partial t}\times\boldsymbol{E}\right]dV$ or $d\boldsymbol{F}=-\frac{\partial}{\partial t}\frac{1}{4\pi}[\boldsymbol{E}\times\boldsymbol{H}]dV$

To see the details of this force $d\boldsymbol{F}_2$ overlooked by the inventor, regard Figure 1. Here is shown the magnetic displacement current, with the plates A, B removed for greater clarity. Such an alternating magnetic flux, however, by Faraday's law, will be linked by an induced electric field as shown in the figure. This induced electric field is in just the right space position to act on the electric charges on the plates, A, B, arising from the current i, and causes a mechanical force to act on them. The induced electric field is in time phase with the electric charges so that this mechanical force is always in the same direction, but pulsating.

Unfortunately for the inventor, the time average of the force on the plates A, B is just equal and opposite in direction to the time average of the force on the field poles, correctly estimated by the inventor. Therefore the answer to the inventor's second question is "No, the unbalanced force on the space-ship cannot drive it on its journey."

However, the electric field and the magnetic field in the space between the plates are in time quadrature, so that while the two mechanical forces give a zero average resultant, the instantaneous resultant is not zero. We may answer the inventor's first question, "Yes, there will be an unbalanced net force on the space-ship of the order of magnitude estimated by him, but it will be an alternating force."

Neither the law of conservation of energy nor the law of conservation of momentum are generally true if applied only to the material parts of a system if electromagnetic phenomena are involved. However, we may regain these two laws if we assign an energy density and a momentum density to empty space. It is customary for this purpose to assign an energy density of $\frac{1}{8\pi}[E^2+H^2]$, and a momentum of $\frac{1}{4\pi}[\boldsymbol{E}\times\boldsymbol{H}]$ to empty space, where $\boldsymbol{E}$ and $\boldsymbol{H}$ are the electric and magnetic field vectors. In the inventor's system, the momentum density $\frac{1}{4\pi}$ $[\boldsymbol{E}\times\boldsymbol{H}]$ in the space between the plates A, B is caused to vary at a rapid rate. By the reinstated law of conservation of momentum there will be an equally large but opposite rate of change in the momentum of the material system. This will correspond to an unbalanced force on the material system whose magnitude will equal $-\frac{\partial}{\partial t}\frac{1}{4\pi}$ $[\boldsymbol{E}\times\boldsymbol{H}]$ integrated through the empty space. This force however will be an alternating one, with time-average zero, for the system shown.

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