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Net Magnetic Force Generation in Open Circuits: A Force Symmetry-Breaking Phenomenon

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Abstract

This paper explores the potential for generating a net magnetic force in open circuits, where the asymmetry of interacting forces can produce a resultant net force. This central concept stems from a nuanced idea that may have been overlooked or remained unnoticed by the scientific community. The simplicity of the proposed idea could lead to the development of propulsion systems capable of repositioning satellites and heavy structures in Earth's orbit or even sending probes to neighboring solar systems within our lifetime.

This work originates from a thought experiment. Before diving into it, let's consider two electrons moving perpendicular to each other, both approaching a common origin. Due to the Lorentz force and Biot-Savart law, these electrons will experience equal forces perpendicular to their velocities, though in distinct directions, seemingly violating Newton's third law.

Now, imagine two wire loops carrying currents. If we neglect the retardation effect[1], Newton's third law mandates that they must exert equal and opposite forces on each other. Can we design the loops' geometry and orientation to create a scenario, similar to the electron experiment, where interaction forces act in different directions without canceling each other out?

A strict physicist might immediately assert that this is impossible. Indeed, the mathematics presented in the Methods section proves that any two closed loops exert equal and opposite forces, resulting in overall cancellation. However, a question immediately arises: if two closed loops must produce equal and opposite forces, does removing part of a loop break this symmetry? As we will subsequently see, open circuits can indeed exhibit this force symmetry breaking.

In the study by Mohammadpour [1], it is argued that Newton's Third Law is only locally applicable at the point of interaction between fields and charges,

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where an instantaneous exchange of momentum occurs. It is deemed inappropriate to extend Newton's Third Law to interactions at a distance where retardation effects may occur and the state of the charges may change. Sebens [2] discusses since fields exert forces on charges and, conversely, charges exert forces on fields, the Newton's Third Law is preserved. Without contradicting Newton's Third Law, and using the Lorentz force as defined in equations (6) and (7), we can demonstrate that forces acting on two open wires might not always exhibit symmetry (Please refer to section Methods).

The accuracy of calculated forces using the Lorentz force is difficult to dispute. This is because the Lorentz force is deducible from Faraday's law of induction and Maxwell's equations using the Leibniz integral rule. Since Maxwell's equations offer an accurate description of fields for most classical electromagnetic applications, it's reasonable to consider the Lorentz force equally accurate when representing forces within the mentioned domain of application.

Example and discussions

Consider a scenario where alternating current (AC) passes through a main circuit with two open sections. A dielectric material is placed within these openings, and the wire's cross-section is designed to function as a capacitor. The circuit voltage is sufficient to overcome the gap and maintain current flow. Auxiliary circuits are positioned near the main circuit's open segments to produce a net force in the desired direction. These auxiliary circuits can operate in-phase or out-of-phase with the main circuit, depending on the intended force direction. System symmetries are designed to eliminate any potential net moment. Figure 1 provides a schematic of the circuit. The open section is denoted by O and O' . Auxiliary circuits are placed to the right and left of the main circuit, near the open sections.

The circuit design presented in Figure 1 aims to produce a net upward force. Segments GH and IK , as well as $G'H'$ and $I'K'$, negate each other's effects. KG and $K'G'$ contribute the most to the upward force, while HI and $H'I'$ have lesser contributions, as outlined in equations (7) or (6). The AC in circuit $GHIK$ is out-of-phase with that of $G'H'I'K'$ to prevent force cancellation. The selection of AC current is sinusoidal here. Therefore, the average force is half of the maximum force. There are no limitations on the number of open sections or turns in either the main or auxiliary circuits, allowing for scalable force generation. However, we'll consider a simple application here. A current of 1000 amps is used for both the main and auxiliary circuits. The distance between O and O' is varying and GL and LK lengths are chosen 15cm each. To minimize counteracting force, HI is placed further away at a distance of 25 cm. The secondary circuits are positioned opposite on each side to cancel out the moment produced in the main circuit and maintain symmetry. Figure 2(a) illustrates the average net force for varying distances between point L (in the auxiliary circuits) and the main circuit, ranging from 1cm to 20cm. Figure 2(b) illustrates the effect of distance between the gap OO' on produced average net force.

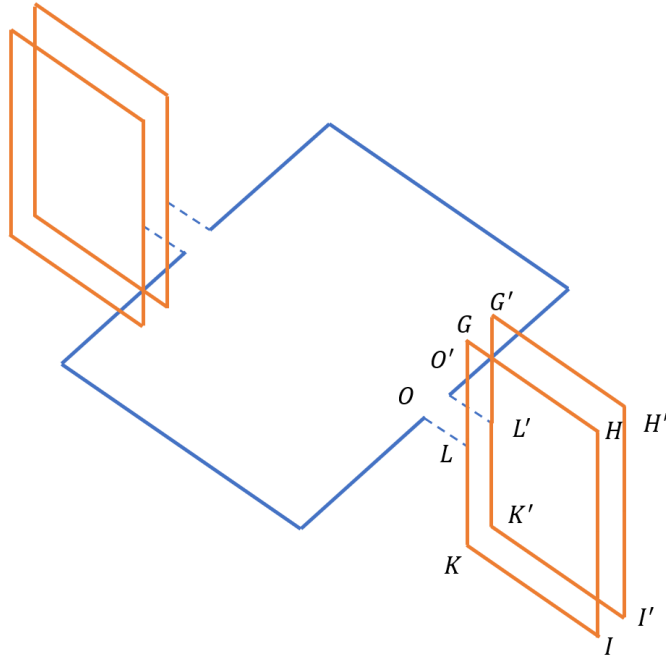


Figure 1: A simplified diagram of a novel AC-powered propulsion system. Open sections act as capacitors (using a dielectric material between points O and O'), while auxiliary circuits are positioned and phased for directional force generation. Auxiliary circuits are identical and symmetrical with respect to the main circuit plane (i.e., $GL = LK$).

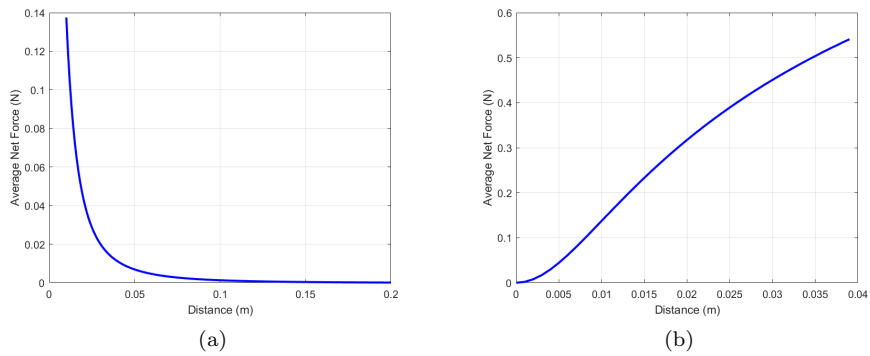


Figure 2: The average net force produced in the setup depicted in Figure 1, as a function of (a) the distance between auxiliary and main circuits (with a fixed $OO' = 1\text{cm}$) (b) the OO' distance (with a fixed initial distance of 1 cm between the main and auxiliary circuits).

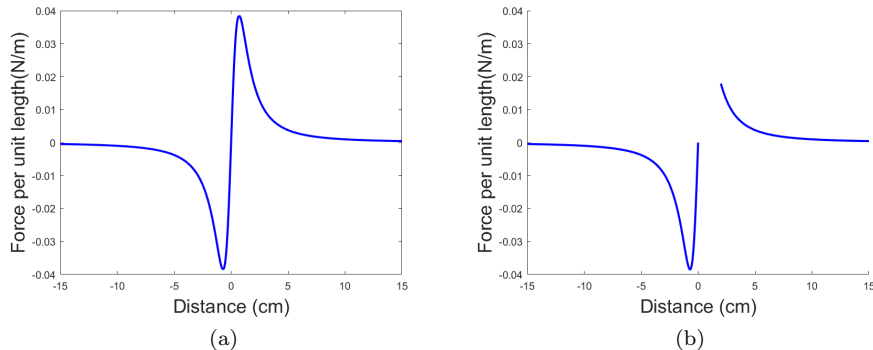


Figure 3: Directional force exerted by a unit length at the midpoint of line KG on a unit length along line NN' for two cases: (a) no open sections, and (b) a 2cm open section. Current in both main and auxiliary circuits is 1000 amps. Distances are measured from point O . Effects from other sections of the secondary wire are not considered.

To demonstrate how open circuit sections break force symmetry, consider the directional force (described by the first integral in Equation (3)) exerted by a unit length at the midpoint of line KG on a unit length along line NN' . This force is plotted for both continuous and discontinuous (with open sections) cases in Figure 3. Figure 3(a) illustrates the symmetry of directional forces in a continuous wire, leading to overall cancellation and no net force production. In contrast, Figure 3(b) demonstrates how open sections break this symmetry, resulting in a non-zero net force.

The potential of current propulsion systems can be significantly enhanced by incorporating multiple turns and open sections. For instance, using 20 turns and 20 open sections, instead of just one, can increase the forces depicted in Figure 2 by a factor of 400. In this specific case, we could potentially generate a force of approximately 5 kilogram-force with a 1 cm distance for the auxiliary circuit and open section. This force is sufficient to accelerate a probe with the mass of Voyager 1, allowing it to cover the same distance travelled by Voyager 1 (up to January 2024) in less than a year. This is not achievable with traditional propellant-based propulsion systems, which require a vast amount of mass for constant acceleration.

Incorporating superconductors into this propulsion system could provide significant advantages and expand its potential applications to include terrestrial and aviation transportation. Unlike traditional electric motors, which lose energy through friction within their mechanical parts, this engine design eliminates such losses due to its lack of moving components. This characteristic paves the way for a highly efficient propulsion system.

Methods

The exact description of the magnetic field around the wire, in the context of electrodynamic causality, is presented in [3]. However, when neglecting the retardation effect and assuming a low rate of change in current, this description simplifies to the more familiar Biot-Savart law [4]

$$\mathbf{B} = \frac{\mu_0 I}{4\pi} \oint \left(\frac{d\mathbf{l}^s \times \mathbf{r}}{r^3} \right) \quad (1)$$

where μ_0 represents the permeability of vacuum and I denotes the current. Furthermore, $d\mathbf{l}^s$ represents an infinitesimal length element of the source, r is the distance from that source element, and \mathbf{r} is the displacement vector. The force exerted by wire A on wire B can be determined using the Lorentz force law

$$F_A^B = I_B \oint_B d\mathbf{l}^B \times \mathbf{B}_A \quad (2)$$

by converting the triple cross products to dot products, it follows

$$F_A^B = \frac{\mu_0 I_A I_B}{4\pi} \oint \oint \frac{d\mathbf{l}^A (d\mathbf{l}^B \cdot \hat{\mathbf{r}}_{BA})}{r^2} + \oint \oint \frac{\hat{\mathbf{r}}_{BA} (d\mathbf{l}^B \cdot d\mathbf{l}^A)}{r^2} \quad (3)$$

where $\hat{\mathbf{r}} = \mathbf{r}/r$ represents the unit vector pointing from the infinitesimal element $d\mathbf{l}^A$ toward $d\mathbf{l}^B$, and r is the distance between these elements. The second term on the right-hand side of Equation (3) implies equal and opposite forces on wires A and B. By expanding the differentials in polar coordinates, it follows

$$d\mathbf{l}^B \cdot \hat{\mathbf{r}} = d\mathbf{r} \cdot \hat{\mathbf{r}} = dr \quad (4)$$

Using the identity (4), the force term (3) can be written as

$$F_A^B = \frac{\mu_0 I_A I_B}{4\pi} \oint_A d\mathbf{l}^A \oint_B \frac{dr}{r^2} + \oint \oint \frac{\hat{\mathbf{r}}_{BA} (d\mathbf{l}^B \cdot d\mathbf{l}^A)}{r^2} \quad (5)$$

For a closed wire, the closed integral $\oint \frac{dr}{r^2}$ equals zero. This is because the integration is performed over a closed loop on a differential of a function, implying that two closed loops within a framework exert equal and opposite forces on each other. The second integral can be named the "reciprocal force," possessing symmetry and directionally dependent on both wires. In contrast, the first term can be termed the "directional force," as its direction depends only on one of the wires and exhibits asymmetry. As previously stated, the directional force vanishes for a closed loop.

Now, consider two open-circuit wires. Each wire has a specific disconnection point, with a sufficiently small gap to act as a capacitor. This allows current to flow depending on the applied voltage and accumulated charge at the disconnection points. Let's denote the disconnection points for wire A as O_A and O'_A , and for wire B as O_B and O'_B (moving in the direction of the current). The interaction forces on wires A and B can be expressed as follows

$$F_A^B = \frac{\mu_0 I_A I_B}{4\pi} \int_A \left(\frac{1}{r_{O'_B}} - \frac{1}{r_{O_B}} \right) d\mathbf{l}^A + \int \int \frac{\hat{\mathbf{r}}_{BA} (d\mathbf{l}^B \cdot d\mathbf{l}^A)}{r^2} \quad (6)$$

and

$$F_B^A = \frac{\mu_0 I_A I_B}{4\pi} \int_B \left(\frac{1}{r_{O'_A}} - \frac{1}{r_{O_A}} \right) d\mathbf{l}^B + \int \int \frac{\hat{\mathbf{r}}_{AB} (d\mathbf{l}^B \cdot d\mathbf{l}^A)}{r^2} \quad (7)$$

Here, r_O denotes the distance between point O and a differential element on the other wire. The net force between the two wires is then expressed as

$$F_A^B + F_B^A = \frac{\mu_0 I_A I_B}{4\pi} \left[\int_A \left(\frac{1}{r_{O'_B}} - \frac{1}{r_{O_B}} \right) d\mathbf{l}^A + \int_B \left(\frac{1}{r_{O'_A}} - \frac{1}{r_{O_A}} \right) d\mathbf{l}^B \right] \quad (8)$$

It can be demonstrated, in many configurations, the net force between the open wires is non-zero. A clear illustration of this occurs when wire A and wire B lie in perpendicular planes, and the differential elements $d\mathbf{l}^A$ and $d\mathbf{l}^B$ are independent of each other.

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Call for collaboration

Ideas are developed and patented regarding this work. I extend an open invitation for collaboration and support to further develop these concepts for the benefit of the scientific community and humanity as a whole.

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