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Proposed motors driven solely by Ampère repulsion

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Abstract. – Two motors, diagrammed in the text, are proposed that are driven solely by Ampère repulsion between colinear current elements. Motor *one* involves sliding contacts with all current leads doubled with current in opposite directions, thereby precluding the presence of any magnetic $\boldsymbol{B}$ field and forces transverse to the current flow. Motor *two* involves mercury contacts that minimize friction and optimize current flow. Forces transverse to the current flow do no work; so only Ampère repulsion exists to drive motor *two*. These motors can demonstrate unambiguously the existence and magnitude of the Ampère repulsion, which then also demonstrates the failure of the Biot-Savart and Lorentz force laws, "Lorentz covariance", and special relativity.

Background. – Following extensive experimentation, Ampère [1] proposed a law for the force between current elements. The force $\mathrm{d}^6\boldsymbol{F}_\mathrm{A}/\mathrm{d}^3r\,\mathrm{d}^3r'$ on a volume element d^3r with a volume current density $\boldsymbol{J}$ at $\boldsymbol{r}$ due to a volume element d^3r' with a volume current density $\boldsymbol{J}'$ at $\boldsymbol{r}'$ is given by

$$\mathrm{d}^6\boldsymbol{F}_\mathrm{A}/\mathrm{d}^3r\,\mathrm{d}^3r' = \left(\boldsymbol{R}/R^3\right)\left[-2\boldsymbol{J}\cdot\boldsymbol{J}' + 3(\boldsymbol{J}\cdot\boldsymbol{R})(\boldsymbol{J}'\cdot\boldsymbol{R})/R^2\right], \tag{1}$$

where $\boldsymbol{R} = \boldsymbol{r} - \boldsymbol{r}'$ and $\boldsymbol{J}$ and $\boldsymbol{J}'$ are in abamperes per cubic centimeter. When $\boldsymbol{J}$ and $\boldsymbol{J}'$ are colinear this Ampère law predicts a repulsive force given by

$$\mathrm{d}^6F_\mathrm{A}/\mathrm{d}^3r\,\mathrm{d}^3r' = JJ'/R^2, \tag{2}$$

which contradicts the traditionally accepted Biot-Savart law,

$$\mathrm{d}^6\boldsymbol{F}_\mathrm{B}/\mathrm{d}^3r\,\mathrm{d}^3r' = \boldsymbol{J}\times\left(\boldsymbol{J}'\times\boldsymbol{R}\right)/R^3, \tag{3}$$

that predicts a zero force between colinear current elements.

The Ampère bridge experiment. – To demonstrate the repulsion between colinear current elements, Ampère [1] performed his Ampère bridge experiment. Two parallel troughs of mercury are connected to a battery. The circuit is completed by a wire bridge between the mercury troughs. When current flows the wire bridge is propelled down the troughs away from the battery. The circuit is diagrammed in fig. 1 to indicate the choice of coordinates for computational purposes. Ampère attributed the observed net repulsive force on the bridge as

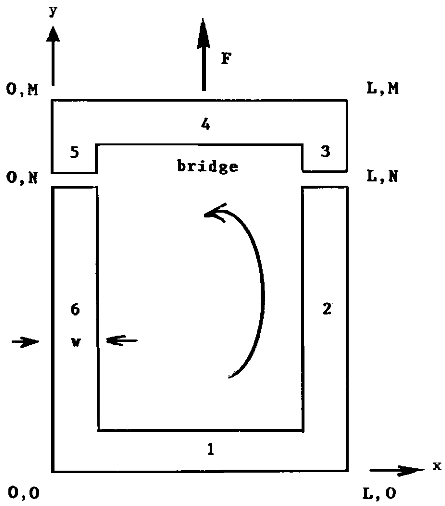

Fig. 1 – Diagram for the Ampère bridge experiment indicating the geometry and choice of coordinates for rectangular leads of width w and thickness t.

primarily due to a repulsive force between the colinear portions of the circuit in contact with each other. The Ampère bridge experiment has been repeated many times subsequently [2–8]. Opponents to the Ampère law and proponents of the Biot-Savart law generally claim that *only* the transverse force on the bridge itself exists to propel the bridge. The two laws are, of course, equivalent for the force between two closed rigid current loops [9–11].

Unfortunately, quantitative confirmations of Ampère's law (1) has not been possible until recently; because no adequate quantitative measurements of the force on the bridge were made and no adequate mathematical analysis was available (the usually assumed fictitious linear current elements giving rise to infinite forces). The Moyssides-Pappas [12] experiment, yielding quantitative results, has now made it possible to compare the observed force on the bridge with a correct mathematical force, derived by Wesley, using volume current elements, for leads of rectangular cross-section [13], as well as for leads of circular cross-section [14]. Reasonable quantitative agreement between Ampère's law (1) and the observations has thereby been finally achieved.

Additional evidence for Ampère repulsion. – A variation of the Ampère bridge experiment is the "rail gun" experiment. The bridge is a metal rod free to slide on two metal rails connected to a battery. The rod is driven to high speeds to be released as a projectile upon leaving the "gun". The force that drives the Graneau [15]-Hering [5] submarine, a copper wedge floating in a trough of current-carrying mercury, is the Ampère repulsion between colinear current elements. The force that drives the Hering pump is primarily Ampère repulsion, as analyzed by Wesley [16]. The oscillations induced in the Phipps-Phipps [17] mercury wedge are due to Ampère repulsion. The rupturing of current-carrying wires [18,19] and liquids [20] is due to Ampère repulsion. Although these additional ways of demonstrating Ampère repulsion between colinear current elements are by order-of-magnitude estimates in agreement with Ampère's law (1), they are not suitable for exact quantitative analysis.

The force on Ampère's bridge. – Referring to fig. 1, the force F' on the bridge in the y-direction due to portions of the circuit not in contact with the bridge may be readily obtained in closed form for the case of thin leads small in comparison to the other dimensions of the circuit by approximating with linear current elements, to yield

$$\begin{aligned} F' &= 2F(1,3) + F(1,4) + 2F(2,4) + 2F(2,5) = \\ &= 2I^2\left\{ \sqrt{1+L^2/M^2} - \ln[(M-N)/M] - \ln(N/L) - \ln\left[1+\sqrt{1+L^2/M^2}\right] \right\}. \end{aligned} \tag{4}$$

The force F'' on the bridge due to the portions of the circuit in direct contact for rectangular leads of width w and thickness t is given by

$$F'' = 2J^2 \int_0^t \mathrm{d}z \int_N^M \mathrm{d}y \int_0^w \mathrm{d}x \int_0^t \mathrm{d}z' \int_0^N \mathrm{d}y' \int_0^w \mathrm{d}x' \big[-2Y/R^3 + 3Y^3/R^5\big], \tag{5}$$

where $Y = y - y'$. Integrating with respect to y and y' yields

$$F'' = 2I^2\big\{-1 + \ln 2 + \ln[(M-N)/M] + \ln(N/L)\big\} + F''_{\mathrm{s}}, \tag{6}$$

where $I = Jwt$; and F''_{s} is a "singularity integral" given by

$$F''_{\mathrm{s}} = -2J^2 \int_0^t \mathrm{d}z \int_0^w \mathrm{d}x \int_0^t \mathrm{d}z' \int_0^w \mathrm{d}x' \ln(Q/L), \tag{7}$$

where

$$Q^2 = (x-x')^2 + (z-z')^2. \tag{8}$$

The integrations may be readily carried out with no approximations, using elementary functions, which for leads of square cross-section, where $t = w$, yields

$$F''_{\mathrm{s}} = 2I^2\big[25/12 - \pi/3 - (1/3)\ln 2 + \ln(L/w)\big]. \tag{9}$$

Combining eqs. (4), (6), and (9), the force on Ampère's bridge from Ampère's law (1) for wires of square cross-section, w^2, becomes, independent of N,

$$F_{\mathrm{A}} = 2I^2\left[C + \sqrt{1+L^2/M^2} - \ln\left(1+\sqrt{1+L^2/M^2}\right) + \ln(L/w)\right], \tag{10}$$

where $C = 13/12 - \pi/3 + (2/3)\ln 2 = 0.498234$ is a constant.

The special case of interest here for which L is as small as possible, which is for $L = 2w$ and $L/M \ll 1$, yields

$$F_{\mathrm{A}} = C' I^2, \tag{11}$$

where $C' = 25/6 - 2\pi/3 + (4/3)\ln 2 = 2.996468$ is a constant.

The absurdity of the Biot-Savart law. – As pointed out by Wesley [21], the Biot-Savart law (3) is *absurd*; as it violates Newton's third law. The force does not act along the line joining the two current elements; and the force on one element does not equal the negative of the force on the other element. The force on Ampère's bridge for leads thin relative to the other dimensions of the circuit permits linear current elements to be used. Since no force exists between the portions in contact, the linear integrations of eq. (3), referring to fig. 1, are easily performed, yielding the Biot-Savart force on Ampère's bridge as

$$F_{\mathrm{B}} = 2I^2\left\{-1 + \sqrt{1+L^2/M^2} - \ln\left[1+\sqrt{1+L^2/M^2}\right] + \ln\left[1+\sqrt{1+L^2/(M-N)^2}\right]\right\}. \tag{12}$$

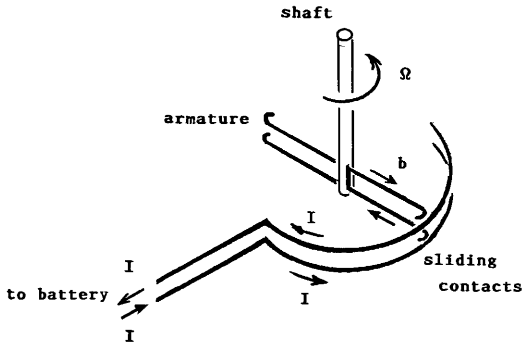

Fig. 2 – Diagram of the proposed motor driven by the Ampère repulsion between colinear current elements to illustrate the electrical principle. Insulated leads are matched by immediately adjacent leads carrying current in the opposite direction.

This Biot-Savart force is quite small, going to zero for $L/M \ll 1$ and $L/(M-N) \ll 1$. It cannot account for the large observed force on the Ampère bridge. Considering the force on the entire circuit, where $M-N$ replaces N in eq. (12) for the force on the source branch due to the bridge, yields

$$F_{\mathrm{B}}(\text{entire circuit}) = 2I^2 \Big\{ \ln\Big[1+\sqrt{1+L^2/(M-N)^2}\Big] - \ln\Big[1+\sqrt{1+L^2/N^2}\Big]\Big\}, \tag{13}$$

which is a nonvanishing "boot-strap" force, permitting work to be done without any energy being necessary. (It is frequently and improperly claimed that the force on the bridge is given by the Lorentz force, $I d\boldsymbol{s} \times \boldsymbol{B}$, where the magnetic $\boldsymbol{B}$ field is computed using the entire current loop. But this involves integrating over the source current in the bridge itself, which then means that a portion of the force on the bridge is supposed to be due to its own current —an inadmissible "boot-strap" force!)

Proposed motor one. – If the Ampère bridge circuit, indicated in fig. 1 is folded over on itself, the left half being superimposed upon the right half to yield a reflected letter C, then all resultant leads become doubled back on themselves. The out and back currents, thus, yield zero net current. As demonstrated by Ampère, such doubled-back currents produce no magnetic $\boldsymbol{B}$ field. Thus, there can be no Biot-Savart-Lorentz force, $\boldsymbol{J}\times\boldsymbol{B}/c$; and the transverse Ampère forces vanish. The only force that remains on the bridge is the local Ampère repulsive force between colinear current elements, given by eq. (11), that acts at the contacts.

These considerations then lead to the proposed motor diagrammed in fig. 2. The doubled-back leads carrying currents in opposite directions may be separated by only the thickness of their insulation. The motor armature may be regarded as the Ampère bridge, portions 3, 4, and 5 in fig. 1, doubled back on itself. The immediate adjacent circular leads and the remaining circuit correspond to portions 1, 2, and 6 in fig. 1. The torque T to drive the motor is then given by

$$T = bF_{\mathrm{A}}, \tag{14}$$

where b is the distance between the sliding contacts and the center of the shaft and where the Ampère repulsion F_{A} at the two sliding contacts is given by eq. (11).

Proposed motor two. – The rotor of the proposed motor, as diagrammed in fig. 3, consists of a conducting rod with two copper end disks, whose rims are immersed in mercury troughs. The rotor replaces the bridge in Ampère's [1] bridge experiment.

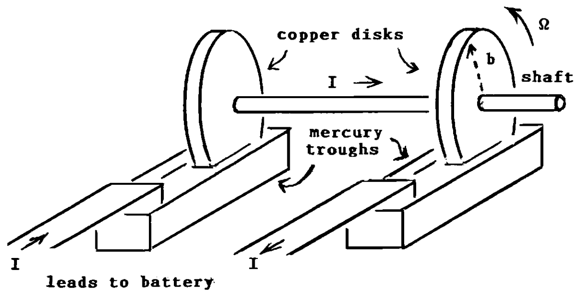

Fig. 3 – Proposed motor with copper disks and shaft, that replace the wire bridge of Ampère's original experiment, connected electrically in two mercury troughs.

The repulsive force acting on the lower rims of the disks may be likened to the force delivered to an undershot water wheel. It is only the force acting transverse to the radius of the disk that drives the motor. The current leads should be, thus, such as to deliver the current as close as possible to the rims of the disks and in the tangential direction, as indicated in fig. 4.

It may be noted that the current configuration everywhere in the entire circuit remains fixed in space and time, whether the disks rotate or not. Nothing mechanical moves transversely to the direction of the current flow; so no transverse forces can do any work to drive the motor. The only force that can possibly drive the motor must, thus, be longitudinal to the current flow itself. Since the only mechanical portions of the circuit that can move relative to each other to do work are at the contacts between the disks and the mercury in the troughs; the contacts constitute the only seat of action for the force of repulsion between colinear current elements that can deliver mechanical work to drive the motor. The net torque to the motor delivered by the two disks is then again given by eq. (14), where now b is the radius of a disk, and the Ampère repulsion is again given by eq. (11).

The Ampère force driving the two motors determined electrically. – One of the primary problems in the past has been the measurement of the force on Ampère's bridge mechanically due to static friction. In contrast, the motors proposed here permit the Ampère force acting to be determined accurately by electrical means only. In particular, the mechanical power delivered to the motors by the Ampère repulsion equals the electrical power delivered by the battery, IV, where V is the battery voltage and I the current, minus the Ohmic losses in the

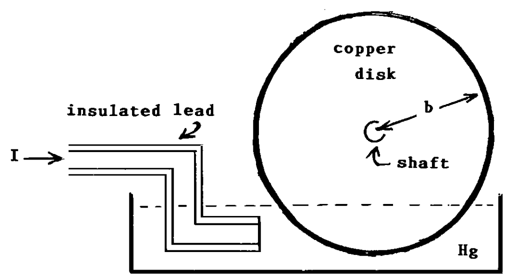

Fig. 4 – Diagram of one of the mercury troughs indicating how the current lead can delivery current tangentially to the under rim of the disk.

entire circuit, I^2R, where R is the resistance of the entire circuit. Since the mechanical power delivered to the motors due to the Ampère repulsive force from eq. (14) is given by $bF_{\mathrm{A}}\Omega$, where Ω is the angular velocity of the rotor, the power balance yields

$$bF_{\mathrm{A}}\Omega = IV - I^2R. \tag{15}$$

The desired Ampère repulsion between colinear current elements is then given by

$$F_{\mathrm{A}} = I(V - IR)/b\Omega. \tag{16}$$

Discussion and conclusions. – The proposed motors should be able to yield striking evidence for the existence of the Ampère repulsion between colinear current elements. They can provide further evidence for the failure of the Biot-Savart law, which predicts zero power delivered by the motors. The motors can provide evidence for the failure of the Lorentz force, that is based upon the Biot-Savart law. In turn, the failure of the Lorentz force indicates the failure of "Lorentz covariance" and "special relativity" that requires "Lorentz covariance".

It should be recognized that large currents of the order of thousands of amperes are required to overcome any friction that may be involved. This means that the proposed devices will have to be large with massive leads. Down-scaling does not seem to be possible.

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