Tangential magnetic force experiment with circular coil

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1. Lorentz force and tangential magnetic force

Lorentz force is always perpendicular to the current, for example, the forces F_a, F_b and F_2 in Figure 1. But the total force on the infinite vertical current I_1 is zero because $F_a+F_b=0$. So, Newton's third law is violated.

If magnetic force is to respect Newton's third law, there should be a recoil force on the vertical current which is F_t. This force is tangent to the current I_1 and called tangential magnetic force. Some physicists claim that tangential magnetic force exists, this claim is supported by some experiments such as the rail gun recoil force shown by Peter Graneau and Ampère's hairpin experiment, see _Lars Johansson's paper_. But these experiments did not convince the physical community and tangential magnetic force is rejected.
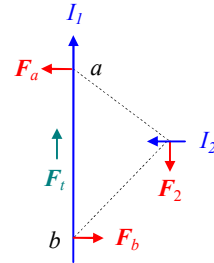
Figure 1

I have carried out an experiment to show tangential magnetic force acting on a circular coil.

2. Principle of the experiment

The principle of this experiment is to make a circular coil to interact with a straight current and to see if the coil rotates. As shown in Figure 2, the setup consists of an n-turns circular coil and a straight fixed lead wire. The current enters into the coil from the fixed lead through a sliding contact, circulates n turns in the coil and leaves through the central lead.
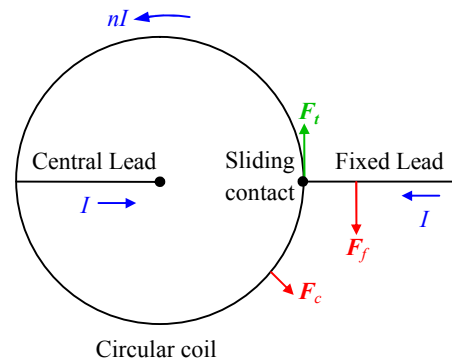
The Lorentz force on the coil F_c is always perpendicular to the circular current and does not create any torque on the coil. So, the latter should not rotate if the magnetic force on the coil is Lorentz force.

Figure 2

But any interaction between 2 objects should respect Newton's third law. As the coil exerts the force F_f on the fixed lead, the fixed lead should exert a reaction force on the coil which is F_t in Figure 2. As F_t is parallel to the coil's current at the contact point, it is a tangential magnetic force and should make the coil rotate. If the coil rotates in the experiment, a tangential force exists on the coil.

3. Result of the experiment

This setup resembles to a homopolar motor except that it contains no magnet. The only magnetic forces are from the currents in the coil and the fixed lead. As the force on the coil is very weak, the contact between the fixed lead and the coil is made by a small ball of mercury which rolls when the

coil rotates (see Figure 3). The central lead is connected to the circuit through a bath of mercury; the coil is suspended to a thread free to rotate. The central lead serves also as the axle of rotation and is maintained in place by a hole in the paper underneath (see Figure 4).

Coil's diameter	Number of turns	Current
6.5 cm	12	4 A

Figure 3

For eliminating the influence of the terrestrial magnetic field, alternating current is first used. When the current is on, the coil rotates to the left showing the torque on the coil made by tangential magnetic force. In subsequent experiments using direct current, the coil rotates to the left too. The torque is stronger than the AC case because the DC current is stronger.

Notice the big sparks at the sliding contact. The voltage is 4V and is unable to create such sparks. In fact, the alternating current comes out of a transformer which has a huge inductance. When the coil rotates, sometimes the contact is lost and the current abruptly cut. Then, the inductance generates a high voltage which creates the big sparks. So, the sparks signal that alternating current is being used. In the experiments using direct current, no spark is visible.

The video of the experiment is on YouTube https://youtu.be/Q5IdfcYViRc.

4. Why does tangential magnetic force exist?

Let us see the direction of the force that a point like current element dI_1 exerts on another, dI_2. Lorentz force is intermediated by magnetic field and can be non parallel to the radial vector joining dI_1 and dI_2.

Figure 4

Figure 5

If in the contrary magnetic force is transmitted in void space with no intermediate, the force should lie on the radial vector as the forces F_1 and F_2 show in Figure 5. The force F_2 is the sum $F_2 = F_t + F_p$, with F_t and F_p being the components tangential and perpendicular to dI_2 respectively. If dI_2 is not perpendicular to the radial vector, F_t is not zero and F_2 possesses a non-zero tangential component.

So, tangential force is subsequent to whether or not the force between 2 point like objects lies on the radial vector. Because magnetic field is not a "hard matter" medium that can transport force transversal to the radial vector, magnetic force should lie on the radial vector and in consequence, tangential magnetic force should exist. This is supported by the rotation of the coil under the effect of tangential force in this experiment.

The existence of tangential force is a general nature of forces acting at a distance in void space. Because there is no medium in void space, all such forces lie on the radial vector, for example gravitational force and Coulomb force. I have shown in ≪ Length-contraction-magnetic-force between arbitrary currents≫ that magnetic force is in fact a form of Coulomb force, then the magnetic force between dI_1 and dI_2 should lie on the radial vector and have a tangential component.

Previously, I have shown the action of tangential magnetic force in other experiments, see «Anti-Lorentzian Motor», «Circular motor driven by tangential magnetic force», «Tangential force motor with regular magnets».

Since Lorentz force law does not predict tangential magnetic force, it is not correct. Then, what is the correct law? The original formula proposed by André-Marie Ampère in 1822 gives a force lying on the radial vector (See page 29 in «Ampère's Electrodynamics» by A. K. T. Assis and J. P. M. C. Chaib). Its expression is the following:

$$dF_2 = -\frac{\mu_0}{4\pi}\left(2dI_1 \cdot dI_2 - 3(dI_1 \cdot e_r)(dI_2 \cdot e_r)\right)\frac{e_r}{r^2} \tag{1}$$

This formula is derived from Ampère's experiments and could be the correct law.

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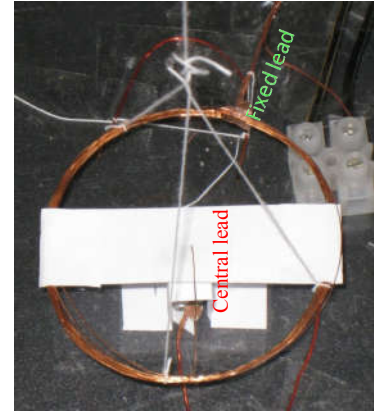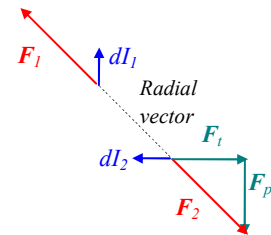## 5. Captions for the video

Tangential magnetic force experiment with a circular coil

The setup

1. The suspended coil

2. Sliding contact using a mercury ball

3. Top view

Experiment using alternating current

4. The coil turns to the left

5. Notice the big sparks

6. The coil turns to the left

7. The sparks are invisible

Conclusion: The current of the fixed lead exerts a tangential force on the coil.

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