Theory about parallel action experiment

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26 March 2013

I have done an experiment named parallel action experiment, which shows the movement of a test coil in a magnetic field that is not allowed by Lorentz force law. Please see the video http://youtu.be/2u5Nadx0mOM and **Lorentz parallel action experiment** blogspot .

The setup of this experiment is shown in Figure 1. The test coil carries a current that is influenced by the magnetic field **B** created by the magnet. The test coil, which is plane and perpendicular to its axle of rotation, can turn only in its plane. The video shows, when the current flows, signaled by the blinking of the led, the coil rotates in its plane.
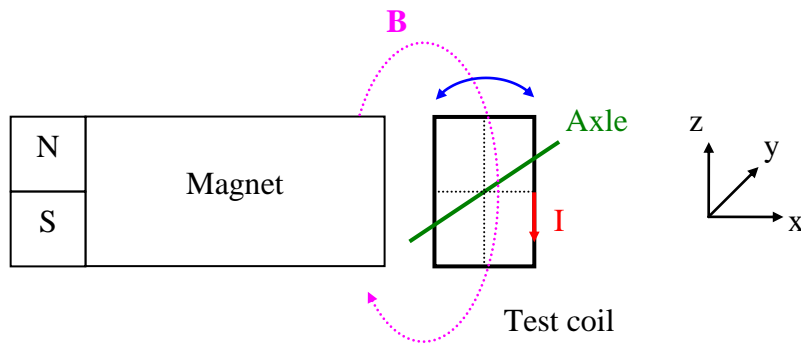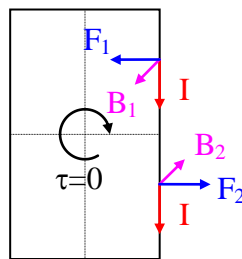

Figure 1

What force makes the coil rotate about the axle? Not tangential force because Lorentz force is always perpendicular to the current (see Figure 2). If the magnetic field is greatly different on the upper and lower part of the coil, like $\mathbf{B}_1$ and $\mathbf{B}_2$ in Figure 2, the corresponding Lorentz forces, $\mathbf{F}_1$ and $\mathbf{F}_2$, could create a torque. But Figure 1 shows this is not the case. So, the Lorentz force law cannot explain the rotation of the test coil.

Test coil

Figure 2

Have we discovered a new force? No. In fact, this phenomenon is well explained by the corrected magnetic force law that I proposed in **Correct differential magnetic force law,** blogspot academia which expresses the differential magnetic force between 2 current element vectors $d\mathbf{I}_1$ and $d\mathbf{I}_2$ as follow (see Figure 3):

$$d^2\mathbf{F} = -\frac{\mu_0}{4\pi}\frac{\mathbf{r}}{r^3}\left(d\mathbf{I}_2 \cdot d\mathbf{I}_1\right) \qquad (1)$$
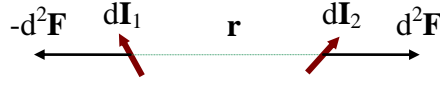

Figure 3

In order to use this law that expresses the force as direct interaction between currents rather than between magnetic field and current, we represent the magnet with an equivalent current loop that creates exactly the same magnetic field. So, the magnetic force is exerted by the currents I_1, I_2, I_3 and I_4 as shown in Figure 4.
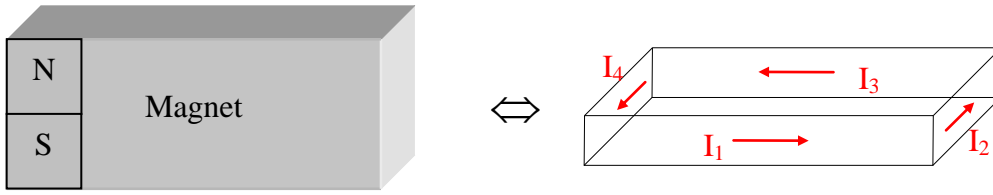

Figure 4

1. Torques

Figure 5 and Figure 6 show the coil positioned with respect to the magnet or the equivalent current loop. According to equation (1) the force between 2 perpendicular currents is zero (scalar product of the 2 current vectors is zero), so currents I_2 and I_4 that are perpendicular to the plane of the coil do not exert any force on it.

Currents I_1 and I_3 are parallel to currents I_5 and I_7 and exert a force on them. The force that I_1 exerts on I_5 is F_1 whose x component is positive:
$$\mathbf{I_1}\cdot \mathbf{I_5} <0 \Rightarrow \mathbf{F}_1\cdot\mathbf{e}_x >0 \qquad (2)$$

The force that I_1 exerts on I_7 is F_2 whose x component is negative:
$$\mathbf{I_1}\cdot \mathbf{I_7} >0 \Rightarrow \mathbf{F}_2\cdot\mathbf{e}_x <0 \qquad (3)$$

So, these 2 forces create on the test coil the torque τ_1 that is counter-clockwise (see Figure 5)
$$\Rightarrow \boldsymbol{\tau}_1\cdot\mathbf{e}_y <0 \qquad (4)$$

Similarly, current I_3 exerts the forces F_3 on current I_5 and F_4 on I_7. These 2 forces create the torque τ_2 that is clockwise (see Figure 6):
$$\mathbf{I_3}\cdot \mathbf{I_5} <0 \Rightarrow \mathbf{F}_3\cdot\mathbf{e}_x <0$$
$$\mathbf{I_3}\cdot \mathbf{I_7} >0 \Rightarrow \mathbf{F}_4\cdot\mathbf{e}_x >0 \qquad (5)$$
$$\Rightarrow \boldsymbol{\tau}_2\cdot\mathbf{e}_y >0$$

2. Rotation of the coil

The experiment tests the rotation of the coil in 2 positions: first, the magnet is behind the coil and the coil rotates counter-clockwise (Figure 5); second, the magnet is before the coil and the coil rotates clockwise (Figure 6).

In the first case, the front current I_1 is nearer to the coil than the rear current I_3 (Figure 5). So, the torque τ_1 is stronger than τ_2 and the test coil rotates in the direction of τ_1, that is, counter-clockwise. In the second case, the rear current I_3 is nearer to the coil than the front current I_1 (Figure 6). So, the torque τ_2 is stronger than τ_1 and the test coil rotates in the direction of τ_2, that is, clockwise.
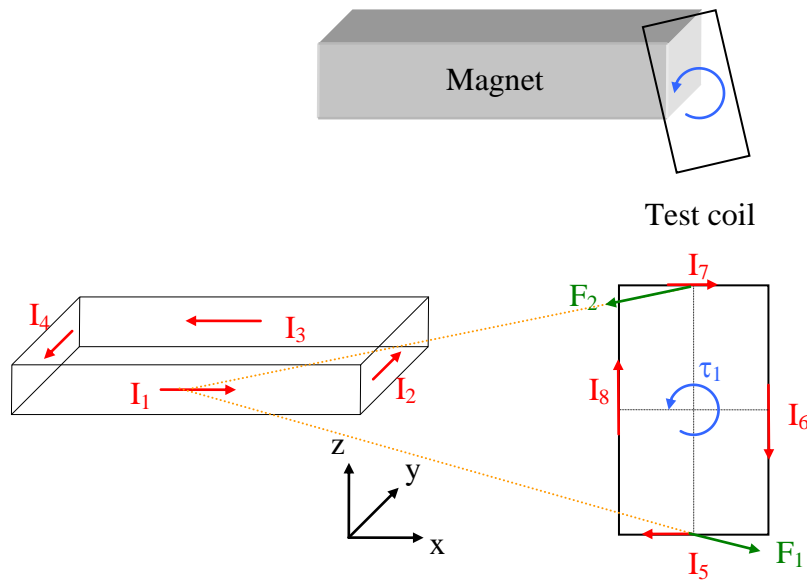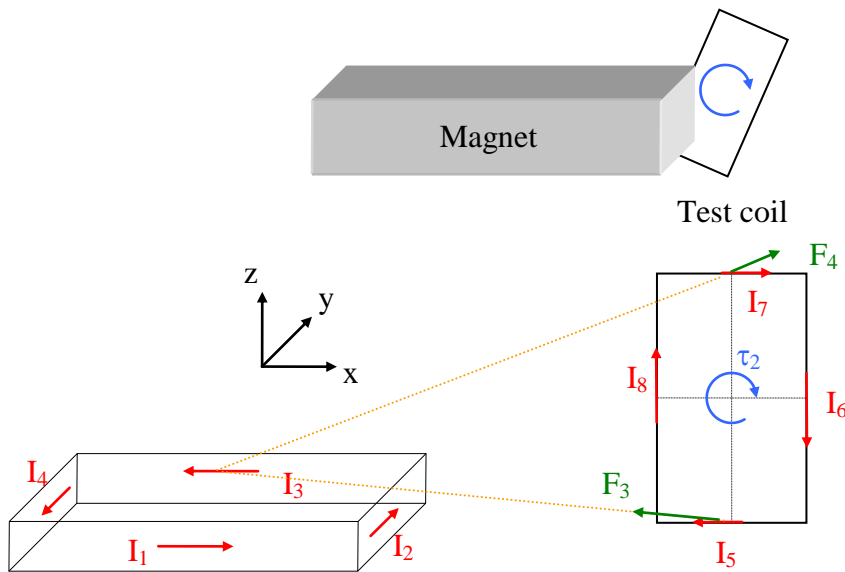
Figure 5

Figure 6

3. Equilibrium inclination

The experiment shows that for constant current, the test coil reaches an equilibrium position and stays inclined. The equilibrium position can be explained by the corrected magnetic force law. In fact, when the long side of the coil is inclined, its current possesses an x component that feels a magnetic force and creates a torque.

Figure 7 shows the situation where the magnet is before the test coil. In this case, the magnetic force from the rear current I_3 is stronger. The long side of the test coil being inclined, its lower half is nearer to I_3 than the upper half and the force F_5 is stronger than F_6. So, F_5 and F_6 create a counter-clockwise torque τ_3 which strengthens with the inclination.

The original torque τ_2 was clockwise, which weakens as the angle of inclination increases. The coil rotates first clockwise, but is stopped by the counter torque $\tau3$. The angle of the equilibrium inclination is such that the torque τ_3 balances exactly the original torque $\tau2$ and the overall torque becomes zero:

$$\tau_2 + \tau_3 = 0 \tag{6}$$

This is why the coil is inclined at equilibrium in the 2 cases. So, the corrected magnetic force law explains the equilibrium of the test coil and allows computing the value of its angle.
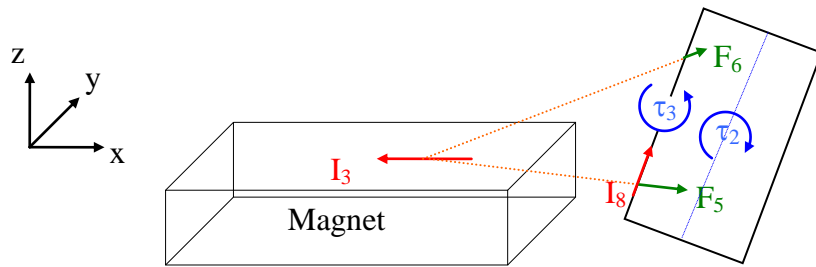

Figure 7

4. Comment

The corrected magnetic force law predicts that, when the magnet is behind, the test coil rotates count-clockwise (Figure 5) and, when the magnet is before, the test coil rotates clockwise (Figure 6), and it predicts also that the test coil should reach an equilibrium position, exactly as the experiment shows. But the Lorentz force law fails to explain these 3 cases.

As the corrected magnetic force law explains the parallel and perpendicular actions experiments (**Corrected law and Perpendicular action experiment,** blogspot academia) and gives exact magnetic force for closed current loop (**Correct differential magnetic force law,** blogspot academia), it describes correctly magnetic force, whereas the Lorentz force law does not.

The parallel and perpendicular actions experiments are not discovered randomly but designed on purpose to demonstrate the flaws of the Lorentz force law. The design of these experiments is possible only with the aid of the corrected magnetic force law, demonstrating its exactness and its strength.