An Experimental Evidence of Energy Non-Conservation

Yu Liang[1], Qichang Liang[2], Xiaodong Liu[3]

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1. Department of Computer Science and Engineering, Michigan State University, East Lansing, MI 48823, USA

2. Department of Nuclear Physics, China Institute of Atomic Energy, P.O. Box 275(10), Beijing 102413, China

3. Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48823, USA

Corresponding Author:

Xiaodong Liu

The present address:
Department of Radiology
Campus Box 8225
Washington University School of Medicine
St. Louis, Missouri 63110
USA
Tel: 314-583-8189
Email: liux@mir.wustl.edu

Abstract

According to Maxwell's theory, the displacement current in vacuum can produce electromotive force on other coil. However, the displacement current in vacuum does not experience electromotive force from other coil. The asymmetrical electromotive forces result in non-conserved energy transmission between any two coils involving one piece of displacement current. In this work, we designed and performed the measurements for such effect. We observed the explicit evidences of non-conserved energy transmission between a toroid solenoid and a parallel plate capacitor. The measured energy increase is well predicted by the numerical estimation.

Introduction

James C. Maxwell introduced the concept of displacement current in 1861. He did not realize that the displacement current can result in energy non-conservation (ENC) in electromagnetic interaction. A typical example is the interactions between a toroidal solenoid and a parallel plate capacitor. As shown in Fig. 1, a parallel plate capacitor connecting in a wire loop is placed in the middle of a toroidal solenoid. Both of them carry alternating currents. The conducting current Ic in the wire and the displacement current Id between the plates compose a closed current loop. Since this loop does not turn around the toroidal solenoid, the alternating current Ic and Id cannot generate electromotive force (EMF) on the toroidal solenoid. On the other hand, the alternating current Is in the toroidal solenoid cannot generate electromotive force on any closed conducting loop which does not turn around the toroidal solenoid. However, the capacitor circuit is not a closed conducting loop because of the gap between the plates. The total electromotive force along the capacitor circuit equals to the integral of the electromotive force along the gap, which is not zero. In this case, the electromotive forces between the toroidal solenoid and the parallel plate capacitor are not equal. The current in the capacitor circuit can be pumped by the electromotive force from the toroidal solenoid. In the mean time, the capacitor circuit cannot pump the current in the toroidal solenoid. Therefore, the energy in this system is not conserved.

Methods and Results

In this work, we designed an innovative experiment to test the ENC effect due to the asymmetrical electromotive forces. The experimental setup is shown in Fig. 2. We have two circuits. The circuit 1 is composed of a toroidal solenoid L_1, a capacitor C_1, and a resistor R_1. The circuit 2 is composed of an inductor L_2, a parallel plate capacitor C_2, a resistor R_2, and a variable capacitor C_V. The diameter of the parallel plate capacitor is 10.0 cm. The distance between the plates is 1.3 cm. The radius of the toroid is 8.5 cm. The transverse area of the solenoid is 4.2 cm^2. The turn number of the solenoid is 96. The values of the elements in the circuits are listed in Table 1. Both circuits have the same resonant frequency at 3765 KHz. A function generator (CA1640-20, Madell Tech. Co.) was used to send sine wave signals at 3765 KHz across the air so that the two circuits are pumped by the function generator respectively. In the mean while, the circuit 1 also pumps the circuit 2 through the coupling of the toroidal solenoid and the parallel plate capacitor.

In the first measurement, we connected the circuit 1 and disconnected the circuit 2. The circuit 1 was pumped by the function generator. We have [1]

$$\varepsilon_{10} = I_{10}R_1 \tag{1}$$

where ε_{10} is the electromotive force on the circuit 1 from the function generator; $I_{10}$is the alternating current in the circuit 1 induced by ε_{10}. The consumed power in the circuit 1 is

$$P_1 = \frac{1}{2}{I_{10}}^2R_1 \tag{2}$$

The measured oscillating amplitude in the circuit 1 was 265±2 mV. The consumed power P_1 was $(3.04\pm0.05)\times10^{-7}$ Watt.

In the second measurement, we connected the circuit 2 and disconnected the circuit 1. The circuit 2 was pumped by the function generator. Similarly, we have

$$\varepsilon_{20} = I_{20} R_2$$

(3)

where ε_{20} is the electromotive force on the circuit 2 from the function generator; I_{20} is the alternating current in the circuit 2 induced by ε_{20}. The consumed power in the circuit 2 is

$$P_2 = \frac{1}{2} {I_{20}}^2 R_2$$

(4)

The measured oscillating amplitude in the circuit 2 was 115±2 mV. The consumed power P_2 was (5.7±0.2) $\times 10^{-8}$ Watt.

Finally, we connected both circuits. There was an additional electromotive force ε_{21} from the circuit 1 to the circuit 2.

$$\varepsilon_{21} = I_{21} R_2$$

(5)

where I_{21} is the current in the circuit 2 induced by ε_{21}. There is a phase difference of $\frac{\pi}{2}$ between ε_{20} and ε_{21} so that they do not interference each other. The induced current $I_{21}$is orthogonal to the induced current I_{20}. The total current I_2' in the circuit 2 is

$$I_2' = \sqrt{I_{20}^2 + I_{21}^2}$$

(6)

The total consumed power in the circuit 2 is

$$P_2' = \frac{1}{2} I_{20}^2 R_2 + \frac{1}{2} I_{21}^2 R_2$$

(7)

The measured oscillating amplitude and the consumed power in each circuit are listed in Table 2. The oscillating amplitude in the circuit 1 did not change. The oscillating amplitude in the circuit 2 was increased to 150±2 mV. The consumed power in the circuit 2 was increased to (9.7±0.2) $\times 10^{-8}$ Watt. The consumed power in the circuit 2 was increased by 4.0×10^{-8} Watt. The numerical estimation of the increased power in the circuit 2 is 3.9×10^{-8} Watt, which is very close to the measured value.

Discussion

A question may be concerned whether the function generator could feed more power into the circuit 1. In fact, the absorbed power from the function generator into the circuit 1 is $\varepsilon_{10} \cdot I_{10}$. The electromotive force ε_{10} is a fixed value for a specific geometry of the circuit. The unchanged current I_{10} indicated that the absorbed power from the function generator to the circuit 1 did not change.

Another question is whether the function generator could feed more power into the circuit 2? The absorbed power from the function generator into the circuit 2 is $\varepsilon_{20} \cdot I_{20} + \varepsilon_{20} \cdot I_{21}$. The first term did not change. The second term is zero since the induced current I_{21} has a phase difference of $\frac{\pi}{2}$ relative to the electromotive force ε_{20}. Thus there is no more energy absorption from the function generator into the circuit 2. The increased power in the circuit 2 is purely induced by the electromotive force from the circuit 1.

If energy were conserved, the increased power in the circuit 2 should be transferred from the circuit 1 so that the oscillating amplitude in the circuit 1 should be decreased. Assuming the ratio of the reduced amplitude in the circuit 1 to its original amplitude is ρ, we have

$$\rho P_1 = \rho^2 P_1 + (P_2' - P_2) \tag{8}$$

Based on the measured data, the value of ρ should be 84.4%. However, we did not see such change. The measured data indicated that the circuit 1 only supplies electromotive force to the circuit 2 without energy output. The extra power consumed in the circuit 2 is the evidence of energy non-conservation.

Conclusion

Our experimental results indicated explicitly that the energy is not conserved through the coupling of a toroidal solenoid and a parallel plate capacitor. In general, the effect of energy non-conservation exists in any system of two circuits if one of them contains a piece of displacement current.

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Figure captions:

Fig. 1: A parallel plate capacitor is placed in the middle of a toroidal solenoid. The transverse cross sections of the capacitor and the toroidal solenoid are shown in this figure.

Fig. 2: Schematic of the two circuits. The circuit 1 is composed of C_1, R_1, and L_1 where L_1 is a toroidal solenoid. The circuit 2 is composed of C_2, Cv, R_2, and L_2 where C_2 is a parallel plate capacitor.

References:

[1] R. P. Feynman, R. B. Leighton, M. Sands, The Feynman Lectures on Physics, Addison-Wesley Publishing Co., Vol. I, (1977) pp.23-5

Table 1: The values of the elements in the circuits

C_1 (Farad)	L_1 (Henry)	R_1 (Ω)	C_2 (Farad)	Cv (Farad)	L_2 (Henry)	R_2 (Ω)
1.96×10^{-10}	9.1×10^{-6}	0.4	5.35×10^{-12}	1.91×10^{-10}	9.1×10^{-6}	0.4

Table 2: The measured oscillating amplitude and the consumed power in each circuit

V_1 (mV)	P_1 ($\times10^{-7}$ Watt)	V_2 (mV)	P_2 ($\times10^{-8}$ Watt)	V_2' (mV)	P_2' ($\times10^{-8}$ Watt)	P_2' – P_2 ($\times10^{-8}$ Watt)
265±2	3.04±0.05	115±2	5.7±0.2	150±2	9.7±0.3	4.0±0.5

Fig. 1

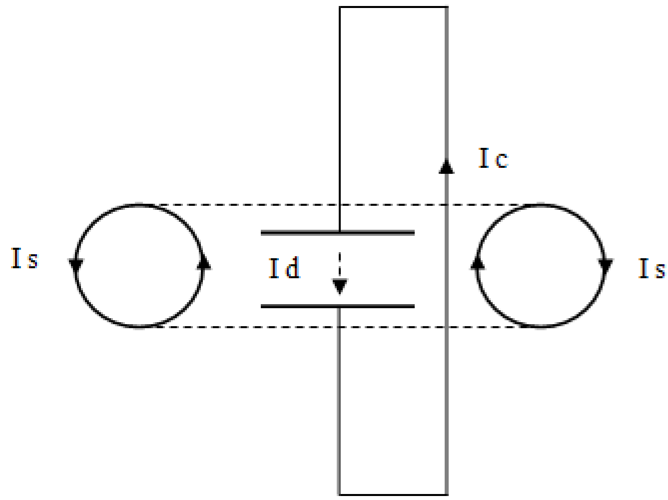

Fig. 2