An experimental result which confirm the fourth electrostatic force

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***Abstract*— There are three type of electric forces, the coulomb force, the image force and the gradient force. The fourth electric force which acts on an asymmetric conductor in symmetric field was proposed by a simulation and named as the asymmetric force [1]. The real existence of this force is confirmed by a simple experiment which uses a tribo-charged Teflon plate and an Al cubic box. A draft concept of this force is proposed. It suggests that the primary cause of this force will be the same as the gradient force.**

I. INTRODUCTION

It is well known that there are 3 type electrostatic forces, the Coulomb force, the image force and the gradient force.

To the contrary, a fourth electrostatic force was found from a simulation analysis of the gradient force and named an asymmetric force [1]. This force acts on an asymmetric non charge conductor (e.g. metal cup) in symmetric field. This is very interesting, but, the concept of this force is not clear and this force is not yet confirmed by a real experiment. Therefore, the aim of this report is to propose a draft concept of this force and confirm it by a real experiment. For that purpose, a new simulation of electrostatic basic problem and a simple experiment are executed.

II. A SIMULATION OF THE BASIC ELECTROSTATIC PROBLEM

Fig. 1. shows a familiar electrostatic problem for freshman. An upper electrode is applied high voltage and a lower electrode is grounded. A non charge plate conductor is inserted by half between the upper and lower electrodes.

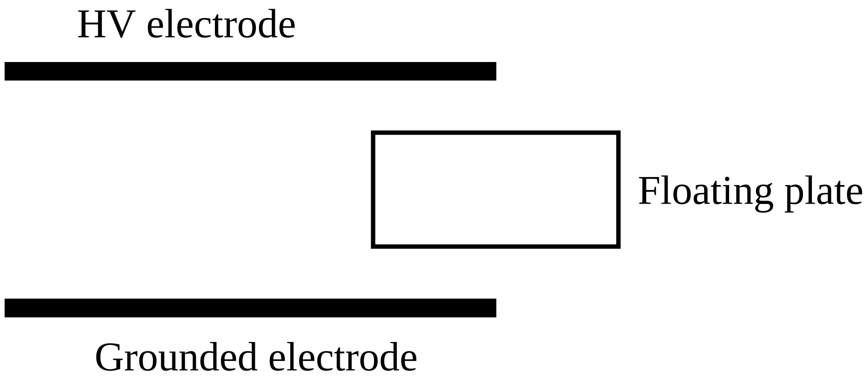

Fig. 1. Freshmen's problem. A floating metal plate which has no charge is inserted by half between electrodes. The upper electrode is applied high voltage and the lower electrode is grounded.

When distance between the upper and lower electrodes is 50mm, width and depth of the both electrode are 100mm each, thickness of the plate is 10mm, width and depth of the plate are 50mm each, high voltage of the upper electrode is 50000 volts, then, the question is the intensity of an electrostatic force which pull the plate to left.

40 years ago, we solved this problem by capacitance model, but, we can solve it by a simulation today. Then, I simulate it by the finite difference method [2], [3], [4]. The result is that electrostatic force which acts on the left surface of the plate is 3.06E-4[N] and electrostatic force which acts on the right surface of the plate is 0.01E-4[N]. Therefore, the answer is 3.05E-4[N].

I get answer, but, there are two more questions. First, what is the cause of this force? Second, why difference between the left force and the right force is so large?

Fig.2 shows answer for those questions. First, line of electric force which is originated from the upper electrode (positive charge) bend to right and inter the upper half of the left surface of the plate. This line of electric force induces negative charge at the surface and pulls the negative charge to left.

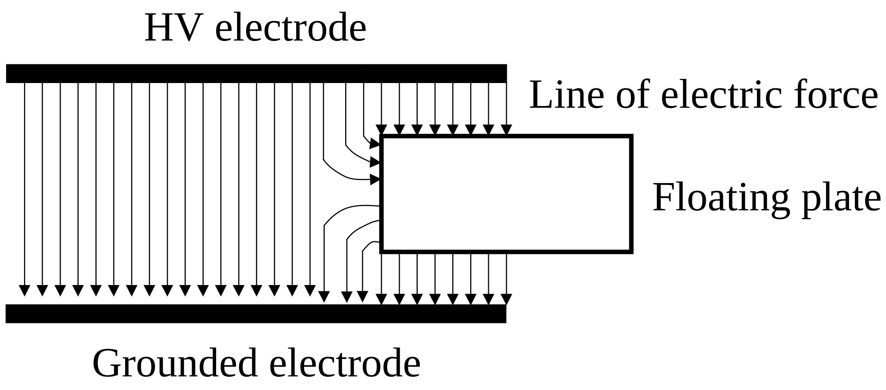

Fig. 2. Lines of electric force around the floating plate which is inserted by half between the high voltages applied upper electrode and the grounded lower electrodes.

On the contrary, at the lower half of the left surface of the plate, positive charges are induced and line of electric force which is originated from this positive charges start to left and bend to the lower electrode. Those positive charges are pulled to left too by the line of electric force. This is the reason of the electric force which pulls the plate to left.
The answer for the second question is very clear, there is a strong electric field at the left surface of the plate which produces strong electric force by the reason. On the contrary, there is no electric field at the right surface of the plate. Therefore, electric force which acts on the right surface of the plate does not occur.
(Notes, those lines of electric force are imaged from simulated potential data)

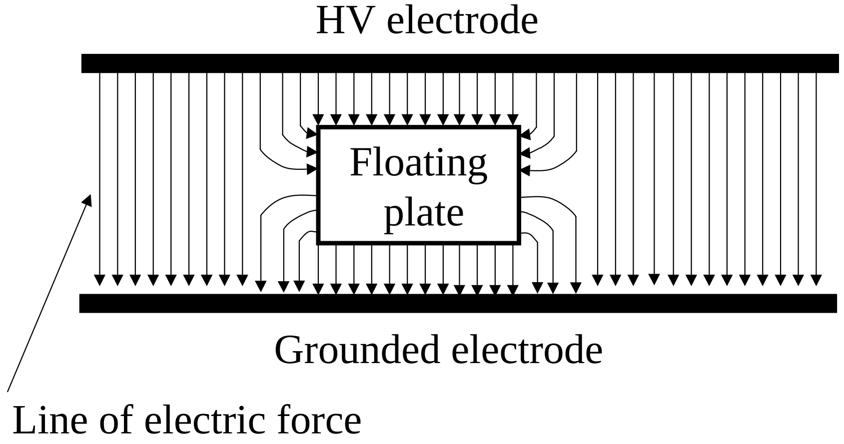

Fig. 3. Lines of electric force around the floating plate which is placed center between the high voltages applied upper electrode and the grounded lower electrodes.

Next, the plate is transferred to the center of the two electrodes as shown in Fig.3. And electric forces which act on the both surface of the plate are simulated. The electric force which acts on the both surface of the plate are the same each other (2.81E-4[N]). The reason is clear. It is because of the same electric fields of the both surface of the plate.

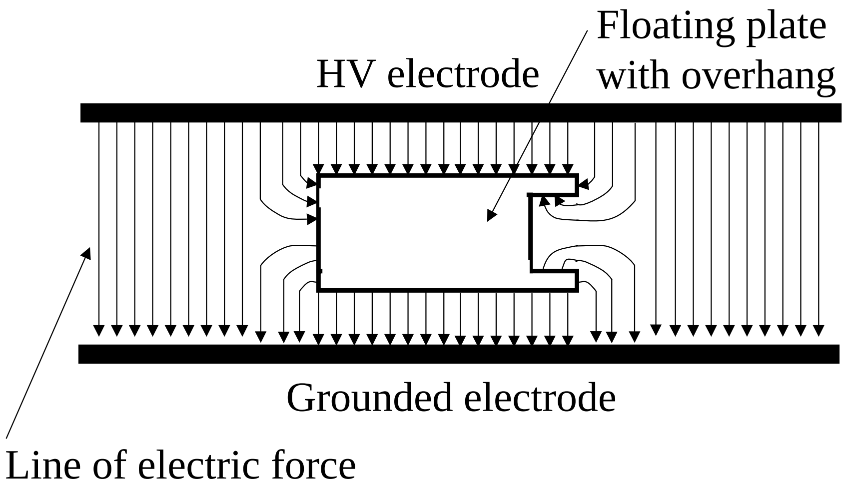

Fig. 4. Lines of electric force around the floating plate with overhangs which is placed center between the high voltage applied upper electrode and the grounded lower electrodes.

Thirdly, overhangs which widths are 10mm and thicknesses are 1mm are added to the right surface of the plate as shown in Fig.4. Then, electric forces which act on the left and right surface of the plate with overhangs are simulated. The result is very interesting, left electric force is 2.81E-4[N] and right electric force is 1.18E-4[N]. As a result, the plate is forced to move to left by this electric force difference.

This phenomenon is similar to the gradient force. Because, both conductors which are placed in an electric field have no charge, nevertheless, both conductors are forced to move by electric force.

The reason of this phenomenon is explained with Fig.4. Namely, line of electric force which is originated from the upper electrode, bend to the right surface of the plate with overhangs, but, bend again to upper and end on the lower surface of the upper overhang. As a result, any line of electric force can not reach to the right surface of the plate where is not covered by the overhang. This condition is similar to the right surface of the plate in Fig.2.

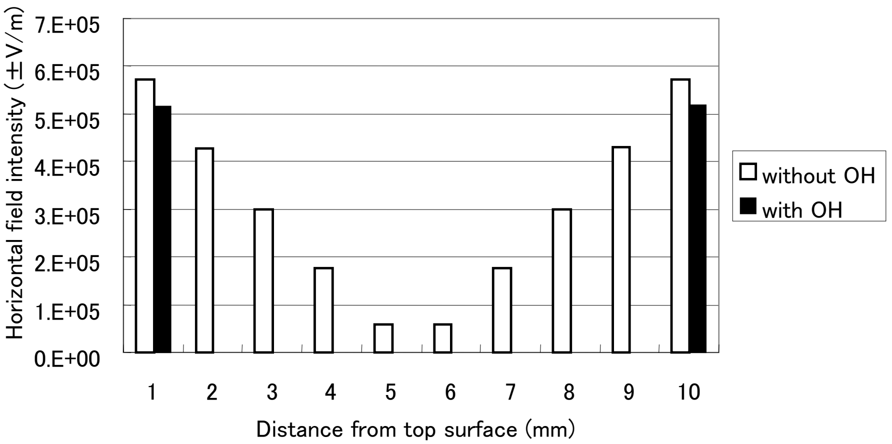

Fig. 5. Horizontal electric field intensity on the right surface of the plate with or without overhangs vs. vertical distance from the top surface of the plate. Notes: where the vertical distance is 0 to 1mm and 9 to 10mm, the right surface of the plate are covered by the overhangs.

The overhangs intercept reaching of line of electric force to the right surface of the plate. Fig.5 shows this effect of the overhangs more clear with simulated electric field intensity distribution over the right surface of the plate with overhangs. The height of the plate is 10mm, it is divided to ten parts and electric field intensity on each 1mm height area is simulated. It is clear from fig.5 that horizontal electric field intensity on this area except overhangs become actually zero after overhangs are added.

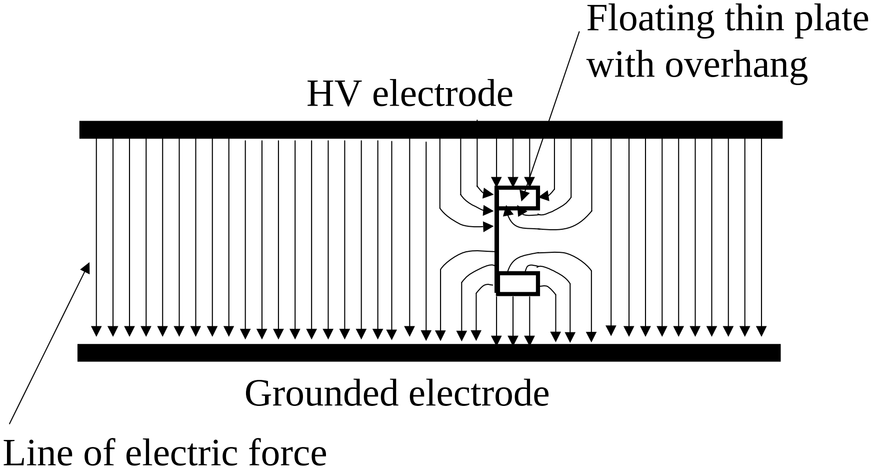

Fig. 6. Lines of electric force around the floating thin plate with overhangs which is placed center between the high voltage applied upper electrode and the grounded lower elec-

trodes.

Does the main body of the plate with overhangs contribute to this effect?
For the purpose,
Fourthly, the main body of the plate with overhangs is cut off as shown in Fig.6 and electric force which acts on the both surface of the thin plate with overhangs is simulated. The result is that electric force which acts on the left surface is 3.11E-4[N] and electric force which acts on the right surface is 1.61E-4[N]. This simulation results without main body are about same as the simulation results with main body. Therefore, the main body does not contribute to the effect which intercept invasion of line of electric force to the right surface.

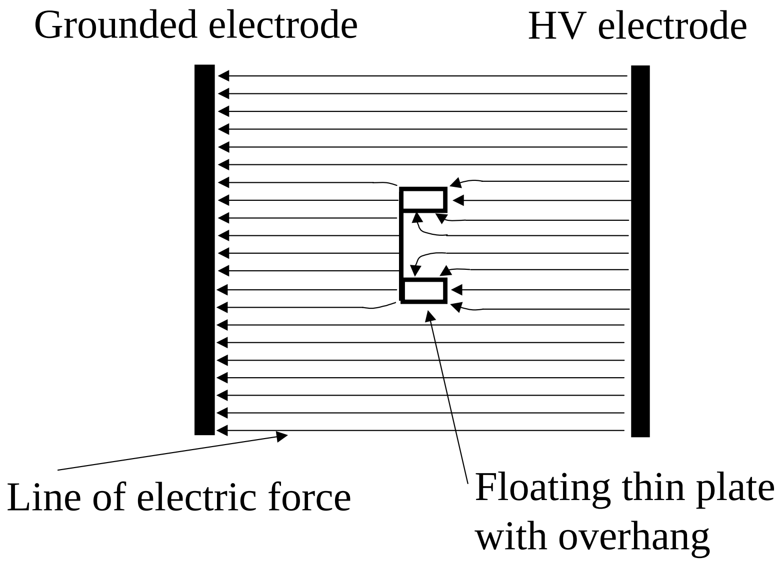

Fig. 7. Lines of electric force around the floating thin plate with overhangs which is placed center between the high voltage applied right electrode and the grounded left electrodes.

In the next place, this force must be confirmed by actual experiment. But, it is too small as compared to the gravity force which acts on the thin plate with overhangs.
Then, fifthly, direction of the electric field is bent by 90 degree as shown in Fig.7. Total electric force which pulls the thin plate with overhangs to left increase from 1.50E-4[N] with Fig.6 to 2.16E-3[N] with Fig.7
This electric force is same order with the gravity force. Therefore, the asymmetric force will be actually confirmed with this arrangement..

III. A EXPERIMENTAL EQUIPMENT AND THE RESULTS

A confirming experiment of the asymmetric force needs high voltage source which produce high intensity electric field with a counter grounded electrode. Usually, a high voltage power supply is used as the high voltage source, but, unfortunately, there is no one in personal research place. Therefore, tribo-charged Teflon plate is used in place of the high voltage power supply.

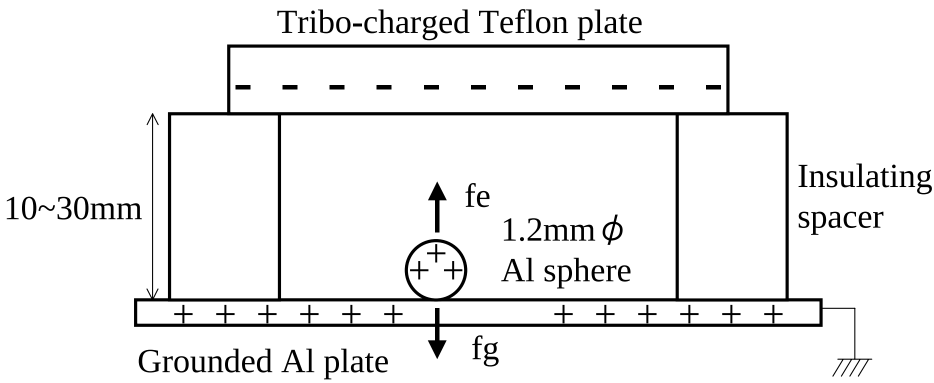

Fig. 8. Schematic diagram of the surface charge density measuring instrument of the tribo-charged Teflon plate

At first, surface charge density of the tribo-charged Teflon plate must be measured. Fig. 8. shows the simple measuring instrument. The base plate is consist of an insulating plate and grounded Al tape on it. Two insulating spacer is placed on the base plate as shown in Fig.8. The height of the spacer is varied from 10mm to 30mm. A small Al sphere is placed on the base plate. The Al small sphere is made from Al sheet. The area of the Al sheet is 4.0 cm^2 and thickness is 12 μ m. The specific gravity of Aluminum is 2.70. Then, the weight of the small Al sphere is 1.30E-5[kg] As a results, The gravity force Fg which acts on the Al small sphere is 1.274E-4[N].

A tribo charged Teflon plate is placed on the spacers as shown in Fig. 8, and strong electric field is produced between the Teflon plate and the grounded Al sheet of the base plate. The tribo-charged Teflon plate has negative charge, then, positive charge is induced in the Al small sphere on the grounded Al sheet. As a results, electric force acts on the Al small sphere. When this electric force is a little larger than the gravity force, then, this Al small sphere start to fly upper and collide with the Teflon plate. This intensity of the electric force Fe can be calculated with the following equation (1).[5].

$$Fe = 1.369 \times 4\pi\varepsilon_0 a^2 E_0{}^2 \qquad (1)$$

Where a is the radius of a conductive small sphere, ε_0 is the permittivity of free space and E_0 is intensity of the electric field.
The radius of the handmade Al small sphere is about 1.2mm, then the intensity of the electric field Es at which the Al small sphere start to fly can be calculated with equation (2).

$$E_s = \sqrt{\frac{0.9306E-4}{4\pi\varepsilon_0 a^2}} \qquad (2)$$

Calculated Es =7.6E+5[V/m].

The Teflon plate were strongly rubbed with nylon cloth by hand 50 times and placed on the insulation spacers immediately as shown in Fig.8. and flying or not flying of the Al small sphere was watched. The height of the spacers are varied 10mm, 16mm,23mm and 30mm. This flying test was repeated 10 times on each height. The results are shown in Fig.9.

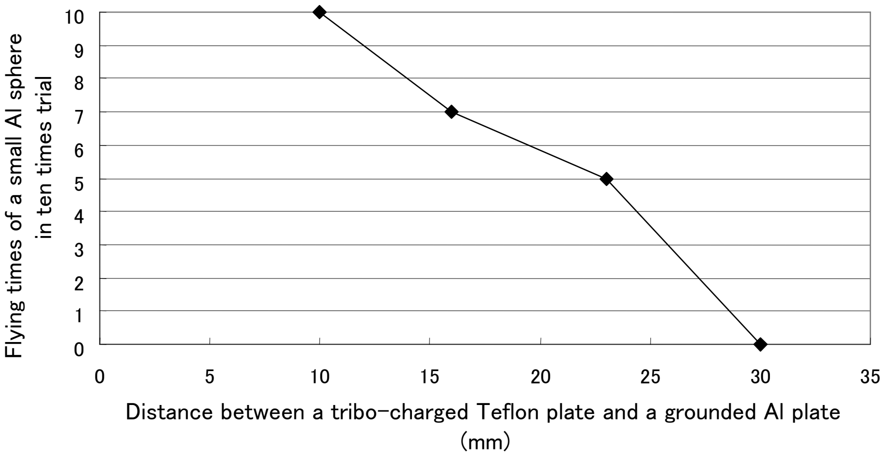

Fig. 9. Flying times of a small Al sphere in ten times trial vs. distance between a tribo-charged Teflon plate and a grounded Al plate.

The Al small sphere succeed to fly 10 times in 10 times trial when the height of the spacer is 10mm, on the contrary, it succeed 0 times in 10 times trial at 30mm height and it succeed 5 times in 10 times at 23mm height trial, those results means that Electric field at 10mm height is far higher than the flying start field Es, on the contrary, electric field at 30mm height is far lower than the flying start field Es and electric field at 23mm height is about same as the flying start field Es .

Then, surface charge density σ of the tribo-charged Teflon plate which make the electric field Es (7.6E+5[V/m]) with 23mm distance between the tribo-charged Teflon plate and the grounded Al tape is simulated . The estimated σ is 6.65E-6[C/m^2]

This value will be used later in a simulation of a displacement distance of the Al right open 1cm cubic box which is hanged between the tribo-charged Teflon plate and the grounded Al tape.

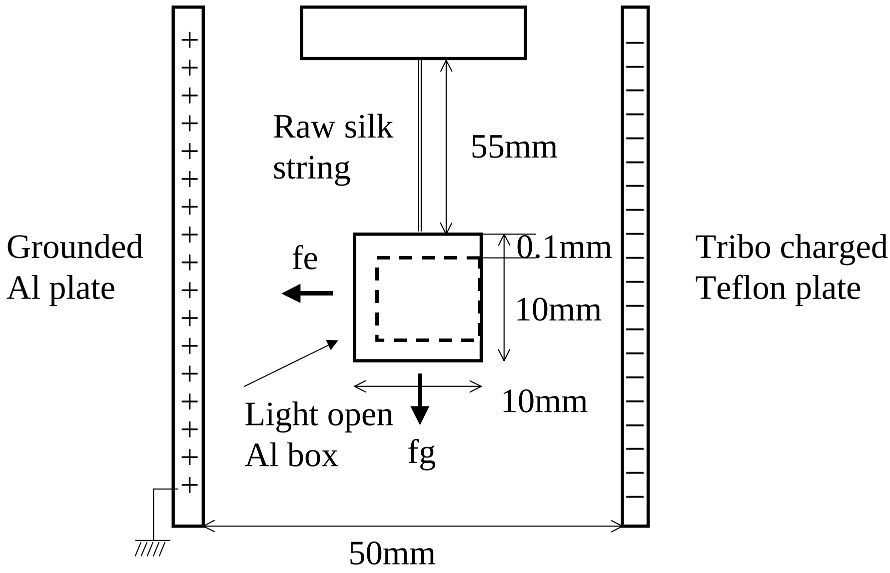

Fig. 10. Schematic diagram of the displacement distance measuring instrument of the right open cubic Al box which is hanged by a raw silk thread between the tribo-charged Teflon plate and the grounded Al plate.

Fig.10 shows a schematic diagram of the simple measuring instrument which will confirm the asymmetric force. At first, 10cm cubic transparent plastic box is prepared. The inner left wall of the box is covered by Al tape and grounded. A right open 1cm cubic box which is made by 0.1mm thickness Al sheet is hanged from the top of the plastic box with a raw silk thread. The tribo-charged Teflon plate was inserted to the plastic box just after tribocharging with the nylon cloth and displacement distance to left of the Al box was measured. Distance between the grounded Al tape and the tribo-charged Teflon plate is 50mm, distance between the tribo-charged Teflon plate and the Al cubic box is 20mm, and distance between the Al cubic box and the grounded Al tape is 20mm. Therefore, the maximum displacement distance of the Al cubic box is 20mm. The length of the raw silk thread is 55mm.

This displacement distance was measured 10 times with the Teflon plate which was rubbed strongly 50 times with the nylon cloth each time. The measured displacement distances are drawn as a solid line in Fig.12. If those measured displacement distance agree with simulated displacement distance, then the electric force Fe which pull the Al right open box to left must be the asymmetric force. As a result, real existence of the asymmetric force will be confirmed. For the purpose of simulating the displacement distance, Fe which acts on the Al 1cm cubic box and pull it to left is simulated with axis symmetry finite difference method.

(Notes: plate and plate with overhang can be simulated with two dimensions finite difference method, but box can not. Therefore, the 1cm cubic box was replaced with a 1cm high and 1cm diameter cup. And, axis symmetry finite difference method was used.)

In this simulation, the measured surface charge density of the tribo-charged Teflon plate (6.65E-6[C/m^2]).is used.
Simulated electric force Fe is 3.937E-4[N].

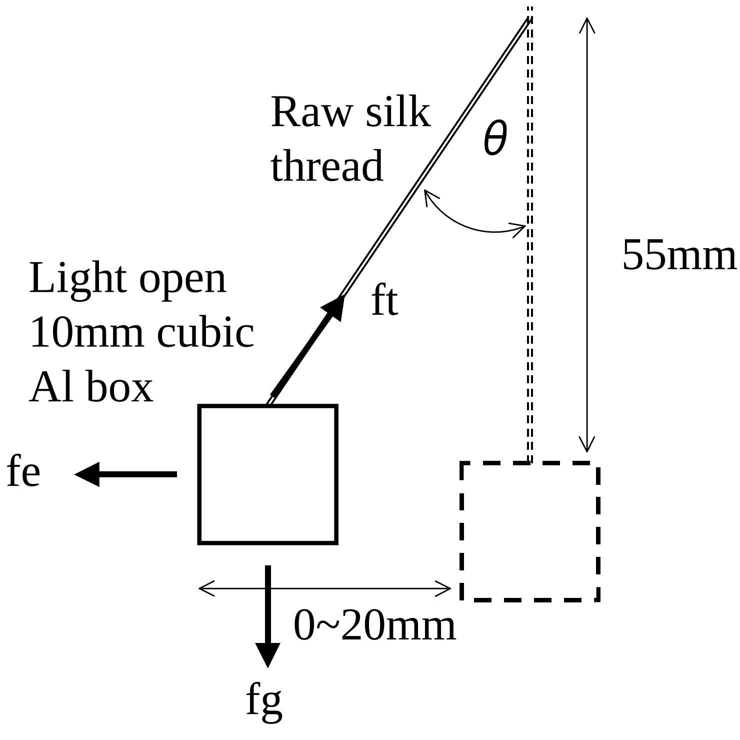

Fig. 11. Schematic diagram of the first and second position of the right open cubic Al box. At first, the cubic Al box is hanged by a raw silk thread (a dotted line), then the box is moved to left by the asymmetric force (a solid line). "fg", "fe" and "ft" are the gravity force, the electric (asymmetric) force and the tension of the thread respectively. "θ" is the angle between the first and second position of the thread. .

Fig.11 shows relationship between the gravity force Fg of the Al cubic box and the electric force Fe which pull the Al right open cubic box to left. The relationship between the gravity force Fg and the electric force Fe is described as

$$Fe = Fg \times \tan\theta \qquad (3)$$

The gravity force Fg of the 1cm cubic box with thickness 0.1mm is 13.23E-4[N] and the estimated electric force Fe = 3.94E-4[N], then

$$\tan\theta = \frac{Fe}{Fg} = 0.2976$$

Fig.11 shows also relationship between the raw silk thread length L and displacement distance of the Al cubic box D. They are described as

$$D = L \times \sin\theta \qquad (4)$$

sin θ can be calculated from tan θ with equation (5)

$$\sin\theta = \frac{\tan\theta}{\sqrt{\tan^2\theta + 1}} \qquad (5)$$

$$= 0.285$$

Then, D= L x sin θ = 15.7mm.
This estimated displacement distance of the Al 1cm cubic box is drawn in Fig.12 as dotted line.

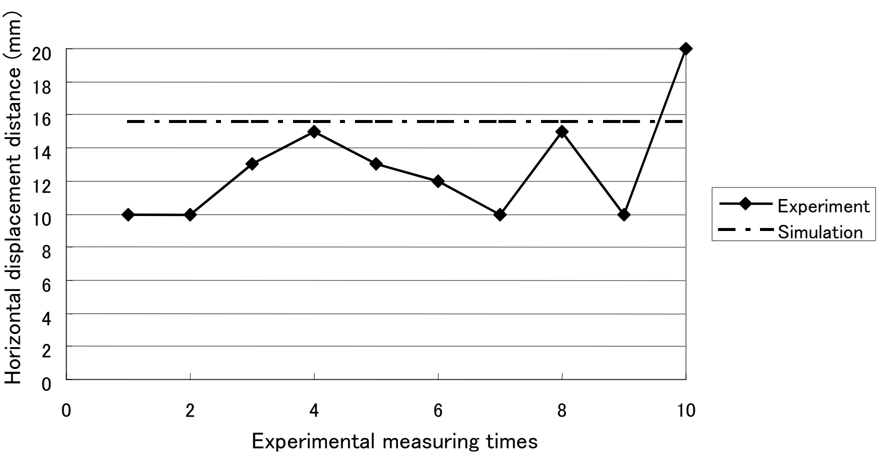

Fig. 12. Horizontal displacement distance of the right open Al cubic box vs. experimental measuring times.

It is clear from Fig.12 that the estimated displacement distance of the Al 1cm cubic box 15.7mm agree roughly with the experiment data 10~20mm
Therefore, this experimentally measured Fe must be the asymmetric force

IV. A DRAFT CONCEPT OF THE ASYMMETRIC FORCE

Today, we have three type electric forces.
First, there are real charge and symmetric (parallel) field. Then, this field gives electric force to the real charge, this electric force is sometimes called Coulomb force.
Second, there are real charge and no field, nevertheless, when this charge is placed near a metal plate, then counter charge is induced at the surface of the metal plate. The real charge and the induced counter charge made an electric field, then this field gives electric force to the real charge, this electric force is called image force.
Third, there are no real charge and asymmetric (convergent) field. However, when a symmetric conductor is placed in the asymmetric field, Positive and negative charges are induced on the left and right surface of the symmetric conductor. This field gives electric force to the positive and negative charge in counter direction each other, but, left side field is stronger than right side field. As a result, total electric force pulls the symmetric conductor to left. This force is called the gradient force.
The freshmen's problem (see Fig.2) is the extreme condition of the gradient force.

Now, we have a new electric force. It is the fourth electric force. This is the asymmetric force.
There are no real charge and symmetric (parallel) field. However, when an asymmetric conductor (e.g. a metal cup) is placed sideways in the symmetric (parallel) field, Electric field of the left side of the asymmetric conductor is about same as the electric field without the asymmetric conductor, but, electric field of the right side of the asymmetric conductor become actually zero because side (peripheral) wall of the asymmetric conductor acts to bend the electric field by 90 degree. As a result, many positive charge are induced at the left surface and no charge are induced at the right surface (Notes, negative charge are induced at the side wall) Then, left side electric field give electric force to those induced positive charge. On the contrary, there are no field and no charge at the right side.
This is the draft concept of the asymmetric force.

The concept of the third electric force (the image force) and the concept of the fourth electric force (the asymmetric force) can be combined to one large concept. The concept is that when a conductor which has no real charge is placed in electric field, if the field or the conductor is asymmetric, then electric force acts on the conductor because electric field of the left side and right side become different each other.

V. CONCLUSION

The real existence of the asymmetric force which acts on an asymmetric non charge conductor in symmetric (parallel) field is roughly confirmed by a simple experiment. It will be perfectly confirmed by a precise experiment.

A draft concept of the asymmetric force is proposed. Namely, when a non charge asymmetric conductor is placed in symmetric (parallel) field, the asymmetric shape of the conductor make a difference of electric field at the left and right surface of the conductor and this difference cause the asymmetric force.

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