Explore the frequency of charging and capacitance change with distance on Kelvin Water Drop

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Introduction

- Invented in 1867 by the British scientist Sir Kelvin William Thomson, this device uses electrostatic induction to use dripping water droplets to generate a voltage.
- it`s usually used or observed in daily life like printer, dust removal, or spark when you are taking off, and so on …, so we select the kelvin water drop to research static electricity.

Principle (how to generate voltage)

Discuss the influence of shape of probes and distance, on electrification efficiency. There are two kinds of shape including two-probes and two-spheres.

Principle (how to generate voltage)

1.A little difference of voltage on two cups. The seed charge is formed because of collision of air molecules with falling water droplets.

2.While the ring and bottle will become same voltage.

3.The water droplet will carry the opposite charge to the ring. The charge will continue to accumulate in the container underneath, resulting in a great potential difference.

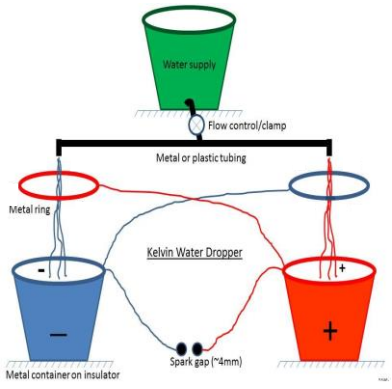

Fig1.kelvin generator (suggest right side with positive charges)

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Principle (Theory of capacitance)

We try to quantitatively analyze the system. By simplifying the system, we build an electrical network with some capacitances. Because of a distance between these materials, there is only a capacitance made by two sparks that we need to consider.

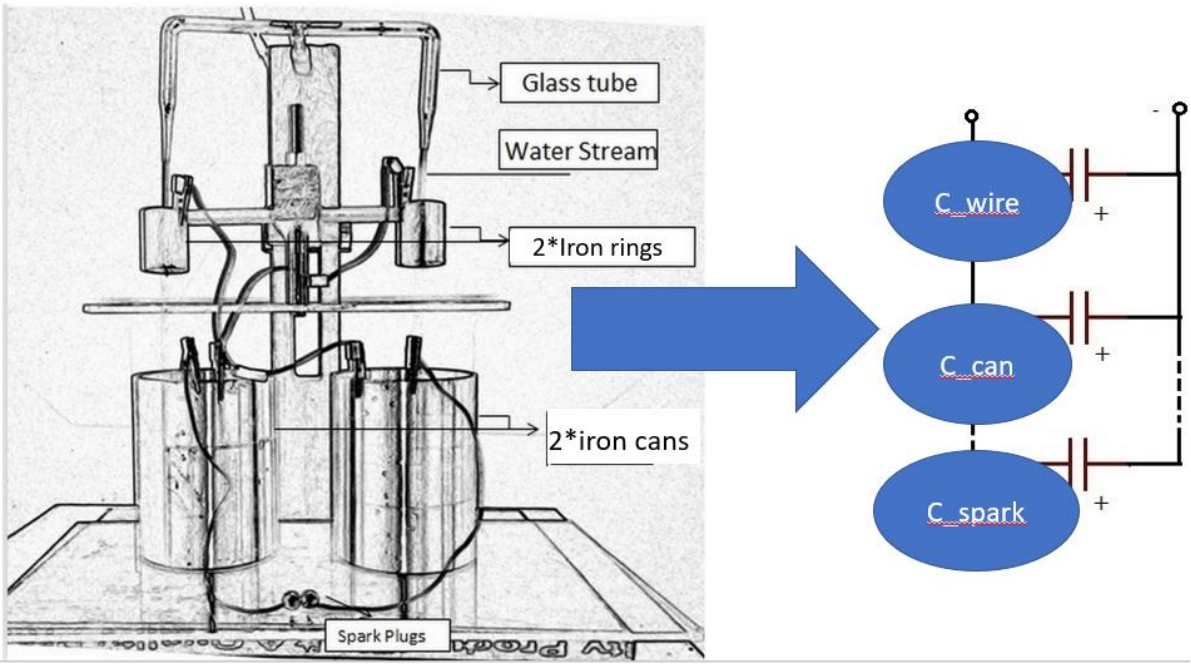
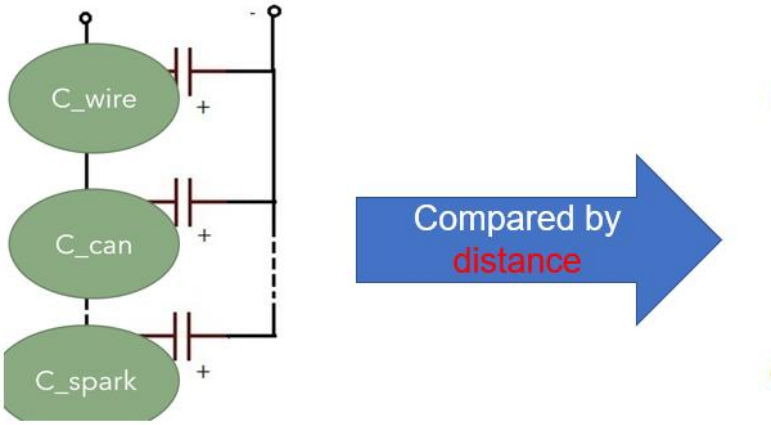


Fig2. Kelvin generator analog to electrical network



$$C_{effective} \approx C_{sp}$$

$$Q_{ac} = C_{sp}V$$

$$Q_{ac} = C_{sp}E_{air}d.$$

Where [E] is the breakdown electric field of air(3 kV/mm) at which the sparks are observed, and [d] is the distance between the plugs.

Capacitance of the two spheres separated by a distance is given by the expression:

$$C_{crowley} = 4\pi\epsilon a[\,1 + 0.5\log\left(1 + \frac{2a}{r - 2a}\right)]$$ Eq1.

Here [a] is the radius of the sphere and [r] is the distance between sphere's centers. So:

Our iron-spherical ball

$a = 2.6cm$

$r = 5.4cm$

$d = 2mm$

$E_{air} = 3000V$

$$\mathrm{Q_{crowley}} = \mathrm{C_{crowley}V} = \mathrm{CE_{air}(r - 2a)}$$

$$\mathrm{Q_{crowley}} = 4\pi\epsilon\mathrm{a}\left[1 + 0.5\log\left(1 + \frac{2\mathrm{a}}{\mathrm{r} - 2\mathrm{a}}\right)\right]\mathrm{E_{air}(r - 2a)}$$

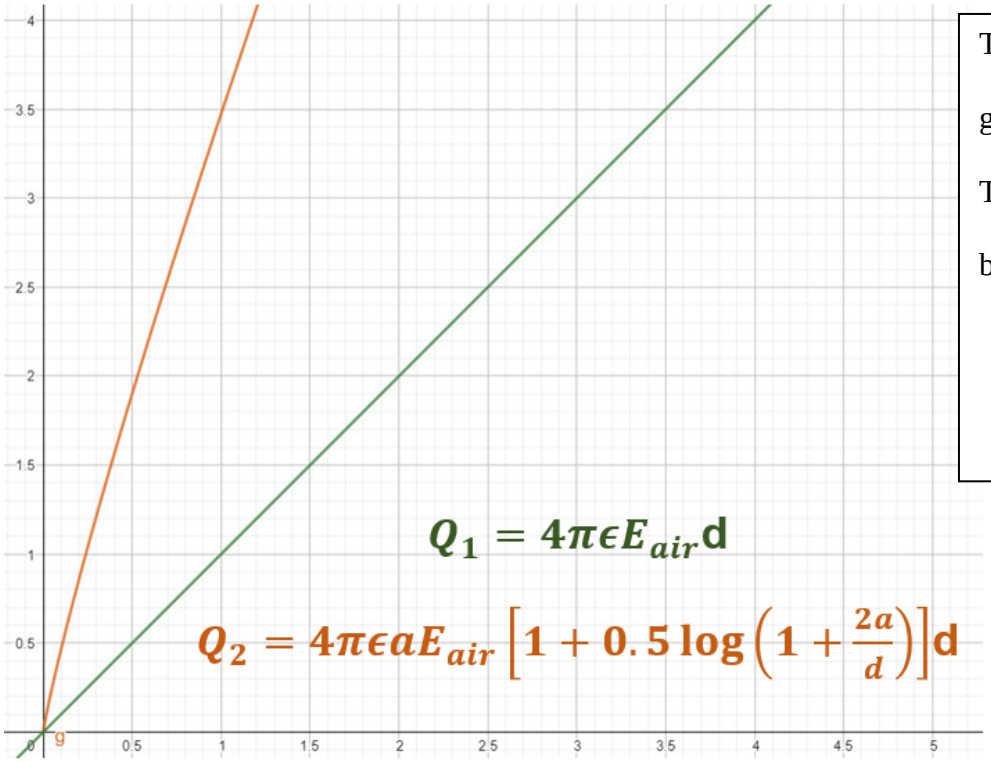
$$\mathrm{Q_{crowley}} = 4\pi\epsilon\mathrm{aE_{air}}\left[1 + 0.5\log\left(1 + \frac{2\mathrm{a}}{\mathrm{d}}\right)\right]\mathrm{d}$$

Here: d = r - 2a, [d] is the width of gap between the spheres.

$$C_{crowley} = 5.43 \times 10^{-6}(F)$$

$$Q_{crowley} = 6.52 \times 10^{-5}\ (\mathrm{C})$$

$10^{-6}Q(C)$



Two-probes:

green

Two-spheres:

brown

$\mathrm{a} = 26\mathrm{mm}$

$\mathrm{E_{air}} = 3000\mathrm{V}$

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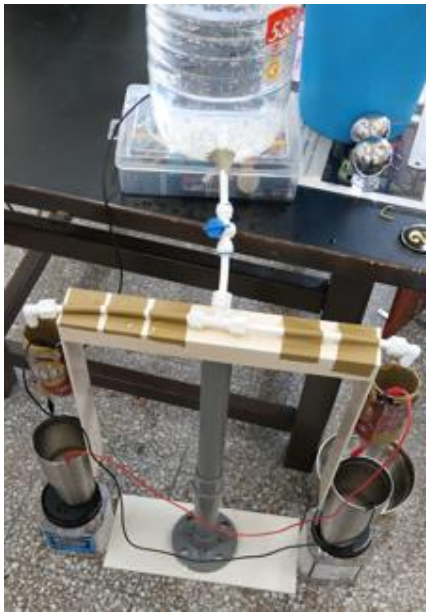
Experiment Method



◆ Components:

1. 5.8L plastic bottle*1

2. 2 points RO fast switch*1

3. 6.35 mm diameter water pipe

4. Acrylic

5. Iron ring*2

6. Iron bottle(900ml)*2

Wide:40cm

Height:78cm

Fig3.Our kelvin generator

◆ Data recorded by sound.

Application: Audacity

Compared with the 60 frames of the film, we think that the sampling rate of general microphones are generally above 44k. It`s better for us to record lighting.

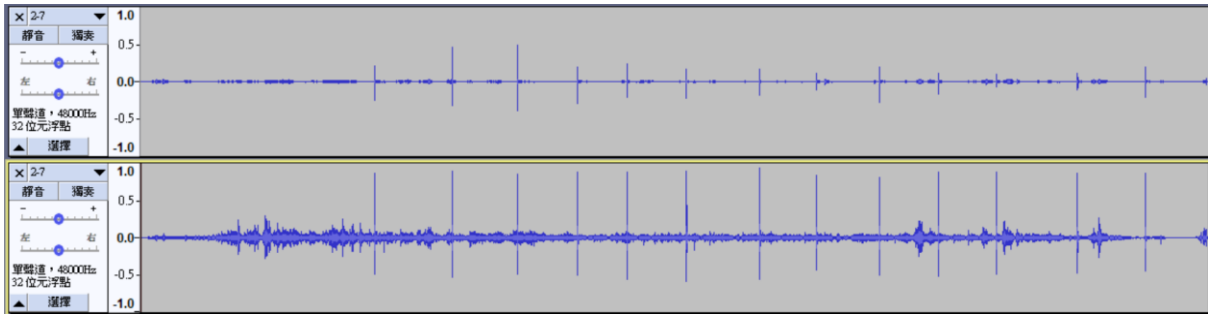
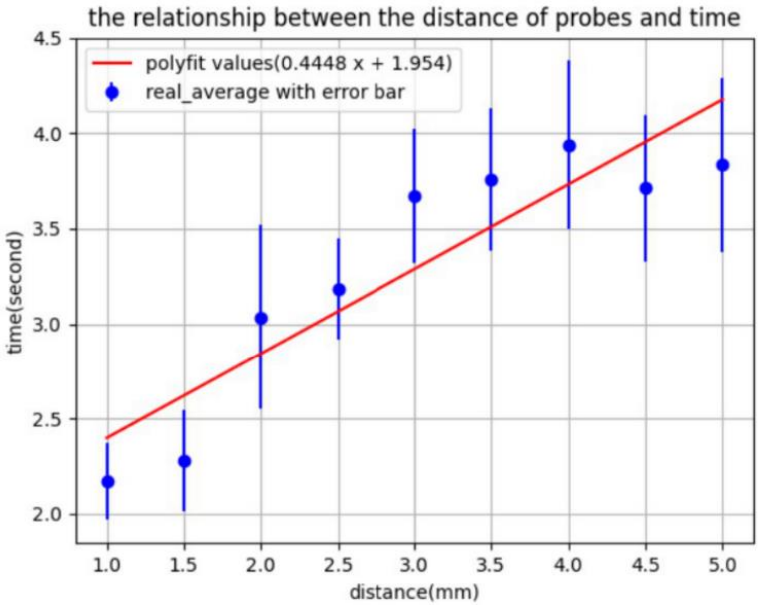
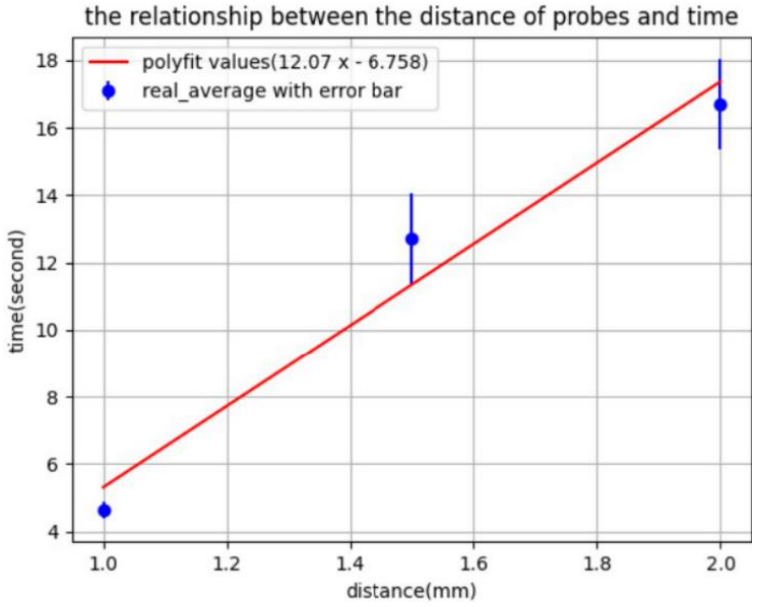


Fig4. The above is the filtered data. We preserve the frequency with over 2khz.

Result (probes of pin)



Result (probes of sphere)



Discussion

1. Wood is easy to lose charge, so we make a setup consist of plastic.

2. The first discharge will take longer than other discharges.

3. Because of high voltage, we can see a phenomenon of scattered droplets.

Fig5. Scattered droplets

Conclusion

1. The longer the distance increases, the lower frequency lighting occurs.

2. It`s easier to discharge than the tip of a sphere.

3. There is a big error in data points. The majority reason we think is a route of lighting is unstable because of molecules of gas. The other reason we think is humidity and temperature because we do not build an independent system.

Reference

Fig1. http://foodscienceandotherstuff.weebly.com/kelvin-water-dropper.html

Fig2. The Kelvin Water Dropper: Converting a physics toy into an educational Device (Shreyash Garg[1], Rahul Shastri[2], B. R. Sivasankaran[3], Luxmi Rani[4], _ Bipin K Kaila[4], and Navinder Singh[4]y [1]S.V. National Institute of Technology, Surat [2]Indian Institute of Technology, Gandhinagar [3]Madras Christian College, Chennai and [4]Physical Research Laboratory, Ahmedabad)

Eq1. Simple Expressions for Force and Capacitance for a Conductive Sphere near a Conductive Wall (Joseph M. Crowley)