21S Experimental Demonstration on Electrostatics phenomena

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(August 15, 2020)

I taught Phys.132 (general physics) on electricity and magnetism in the summer sessions of 2018 and 2019 at the Binghamton University. For students, the use of video in the web sites is very effective for our understanding the essential of the electrostatic phenomena. One can see the detail of the following apparatus for the electrostatic phenomena using the URL for Wikipedia.

Wimnurst machine
https://en.wikipedia.org/wiki/Wimshurst_machine
Electroscope
https://en.wikipedia.org/wiki/Electroscope
Electrophosrus
https://en.wikipedia.org/wiki/Electrophorus
Van de Graaff
https://en.wikipedia.org/wiki/Van_de_Graaff_generator
Leyden jar
https://en.wikipedia.org/wiki/Leyden_jar
Faraday cage
https://en.wikipedia.org/wiki/Faraday_cage

In the lectures of Prof. Walter Lewin (**8.02 X- MIT Physics II: Electricity and Magnetism**), there are so many interesting demonstrations in youtubes. For convenience, we put the times when the demonstrations are presented during the lecture (roughly 50 minutes).

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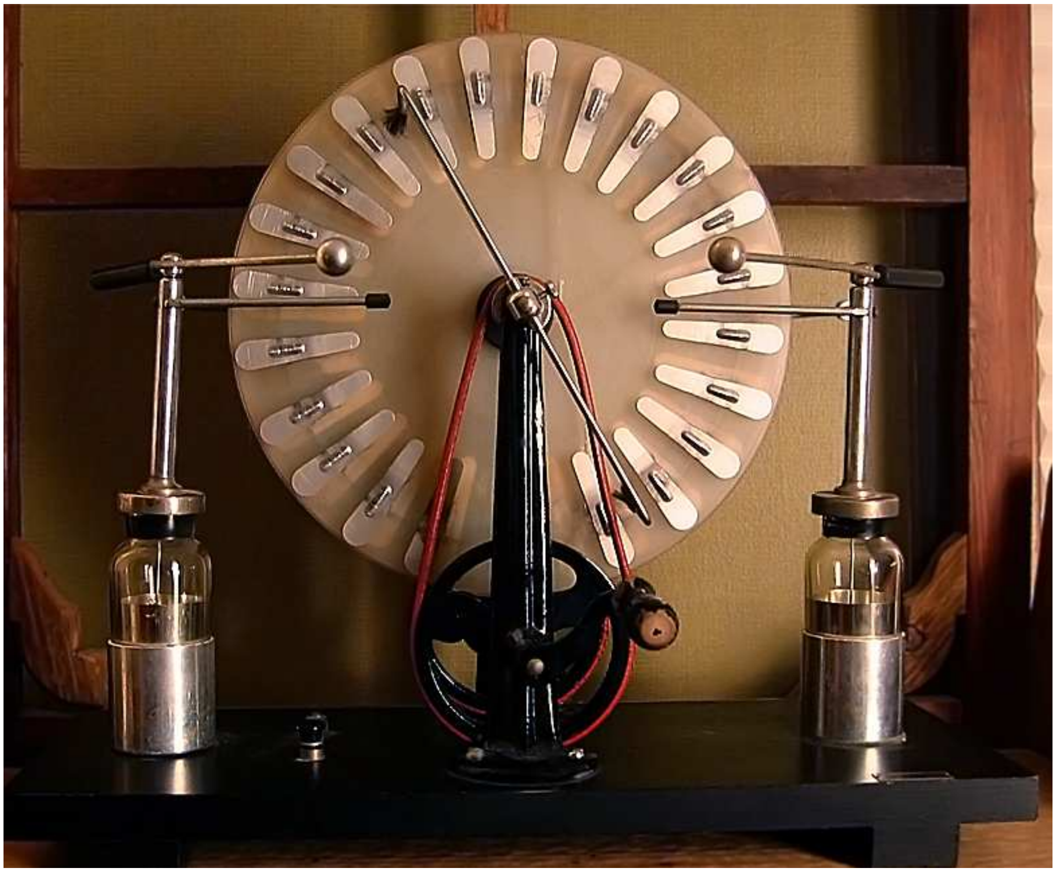
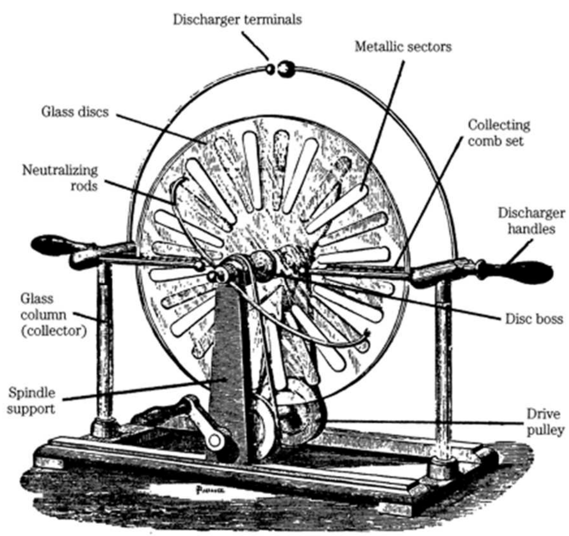
1. Wimhurst machine

https://www.youtube.com/watch?v=Zilvl9tS0Og
MIT Physics Demo -- The Wimshurst Machine
300,750 views



https://nationalmaglab.org/education/magnet-academy/history-of-electricity-magnetism/museum/wimshurst-machine



3-1 James Wimshurst's original design. Electrical Influence Machines, John Gray, 1903

Fig. Schematic diagram of Wimhurst machine.

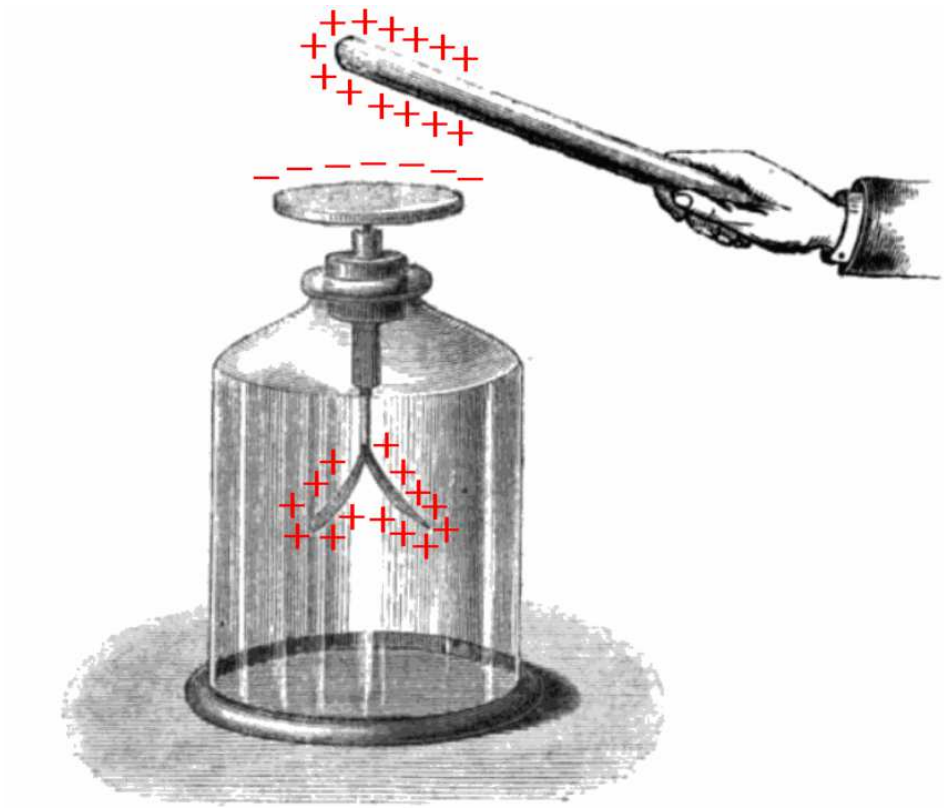
2. Type of charges: evidence of positive charge and negative charge

Prof. Walter Lewin

8.02x - Lect 1 - Electric Charges and Forces - Coulomb's Law - Polarization
https://www.youtube.com/watch?v=x1-SibwIPM4&list=PLyQSN7X0ro2314mKyUiOILaOC2hk6Pc3j&index=3&t=0s
10 minutes/47 minutes

3. Electroscope

https://www.youtube.com/watch?v=aV2HOpO_XFQ
8.02x - Lect 1 - Electric Charges and Forces - Coulomb's Law - Polarization
42:00 43:00 min/47 minutes



4. Electrophorus

https://www.youtube.com/watch?v=K-2KVHp_hZ0

Charging by Induction

((Principle of electrophorus))
Steps 1-4.

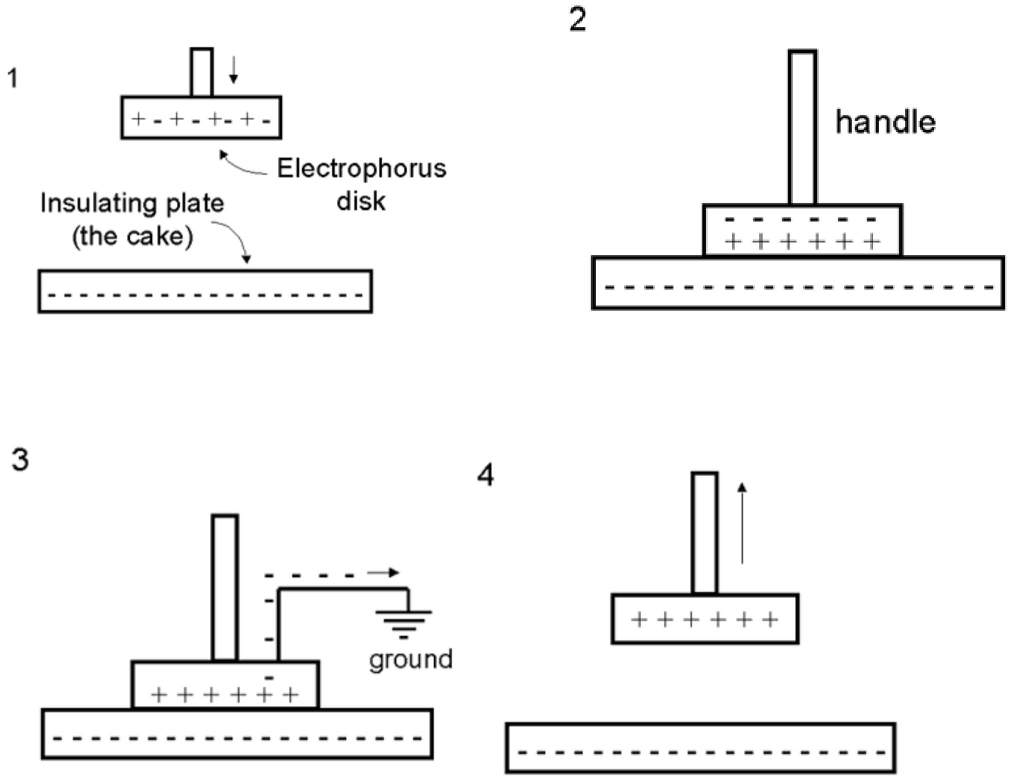


Fig. Principle of electrophorus. Electrophorus disk is made of metals, while the handle is insulator. The induced minus charges on one surface of the metal is discharged to ground by touching human hand with the surface. In this case, the charges of the metal is positive.

Prof. Walter Lewin

8.02x – Lect 5 – E= - grad V, Conductors, Electrostatic Shielding (Faraday Cage)
https://www.youtube.com/watch?v=JhV-GOS4y8g&list=PLyQSN7X0ro2314mKyUiOILaOC2hk6Pc3j&index=7&t=0s
30 minutes/50 minutes

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5. Leyden jar

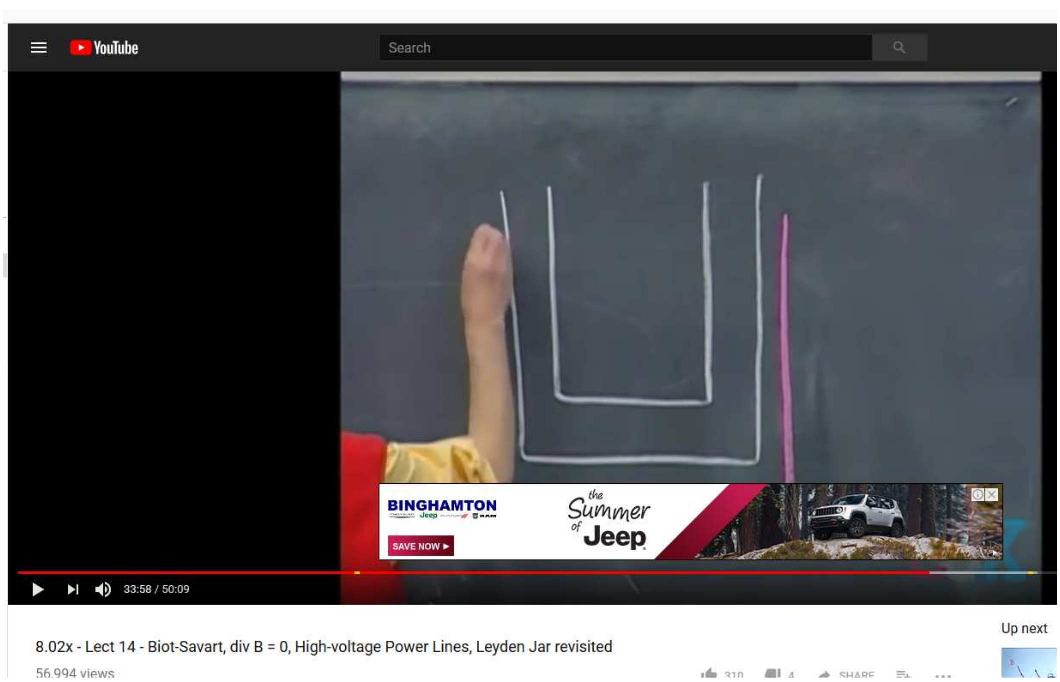
Prof. Walter Lewin

8.02x - Lect 8 - Polarization, Dielectrics, Van de Graaff Generator, Capacitors
https://www.youtube.com/watch?v=GAtAG938AQc
40 minutes/50 minutes

((Explanation)) Lecture 14 (Leyden jar revisited)
Prof. Walter Lewin

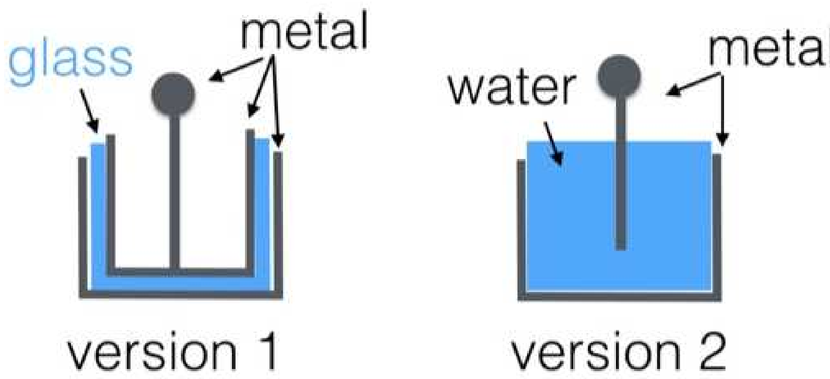
https://www.youtube.com/watch?v=By2ogrSwgVo

33 minutes/50 minutes

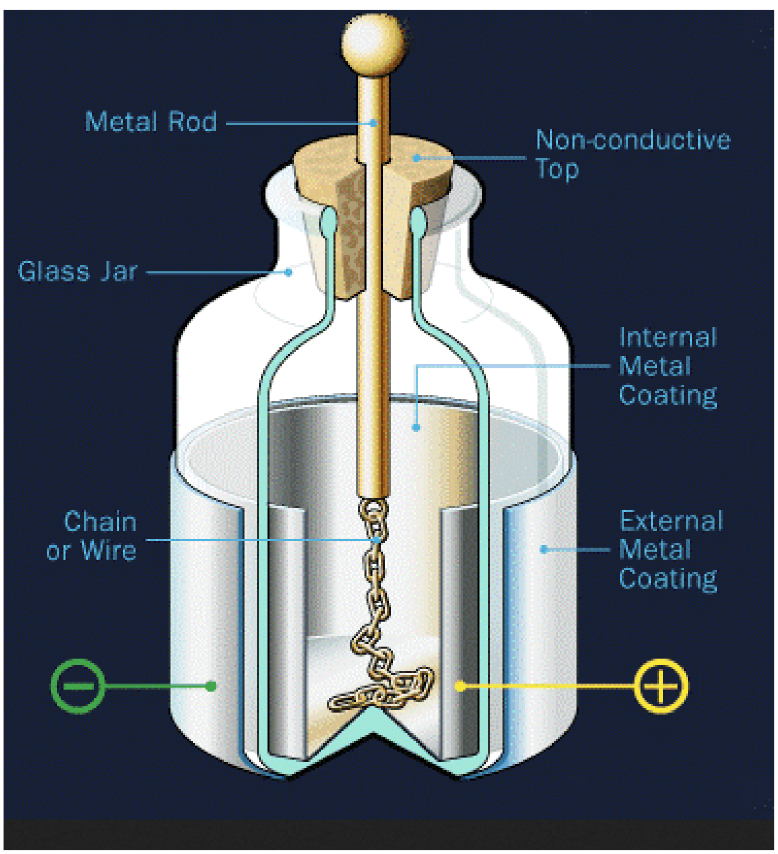


((**Note**)) **Examples of Leyden jar**

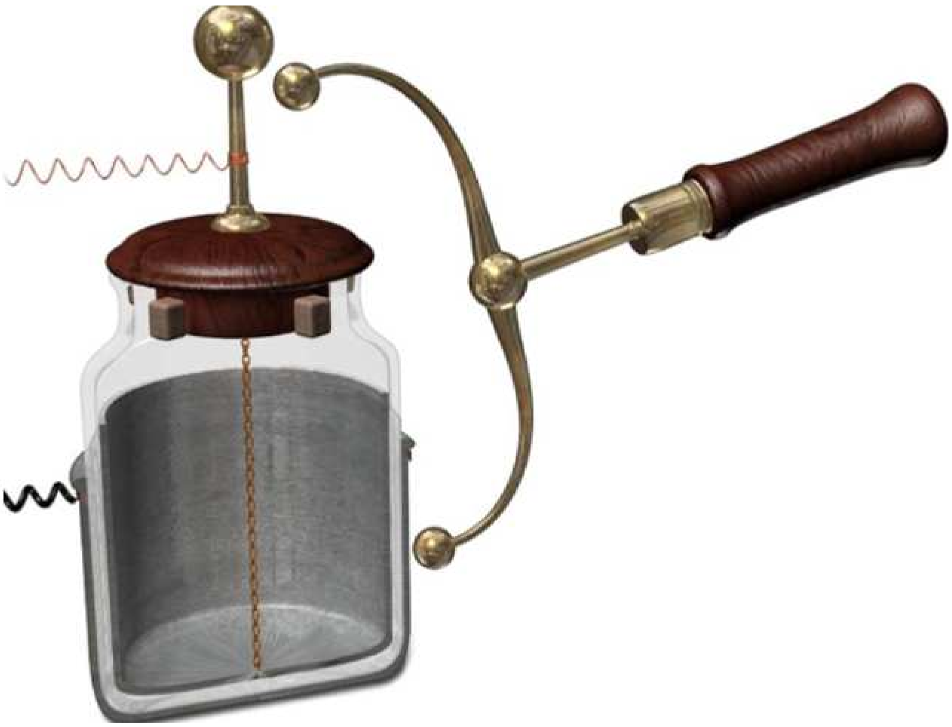
(a)



(b)



(c)



6. Faraday cage

Prof. Walter Lewin

8.02x - Lect 5 - E= - grad V, Conductors, Electrostatic Shielding (Faraday Cage)
https://www.youtube.com/watch?v=JhV-GOS4y8g&t=0s&index=7&list=PLyQSN7X0ro2314mKyUiOILaOC2hk6Pc3j
47:00 minutes/50 minutes

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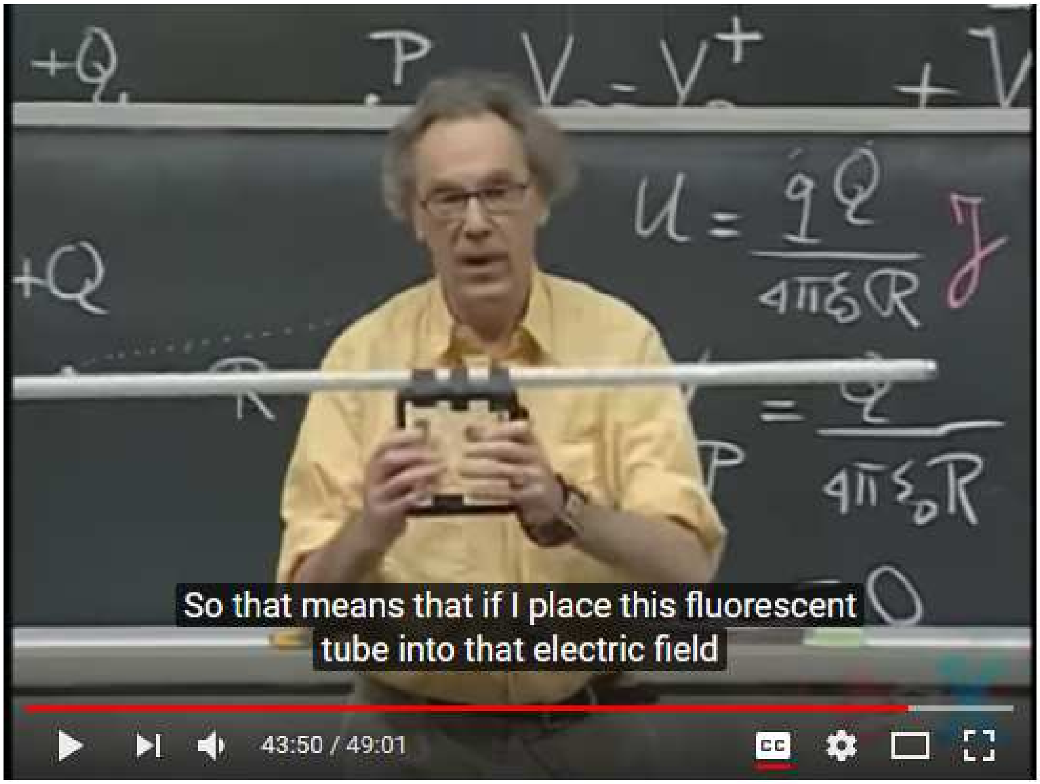
7. Equipotential from Van de Graaff

Prof. Walter Lewin

8.02x - Lect 4 - Electrostatic Potential, Electric Energy, Equipotential Surfaces
https://www.youtube.com/watch?v=QpVxj3XrLgk&list=PLyQSN7X0ro2314mKyUiOILaOC2hk6Pc3j&index=6&t=0s
44 minutes /47 minutes



8. Induction of Conductor-I

Conductor is charged by using electrophorous and check the distribution of electric field inside the conductor.

Prof. Walter Lewin

https://www.youtube.com/watch?v=JhV-GOS4y8g&list=PLyQSN7X0ro2314mKyUiOILaOC2hk6Pc3j&index=6
30 minutes/50 minutes

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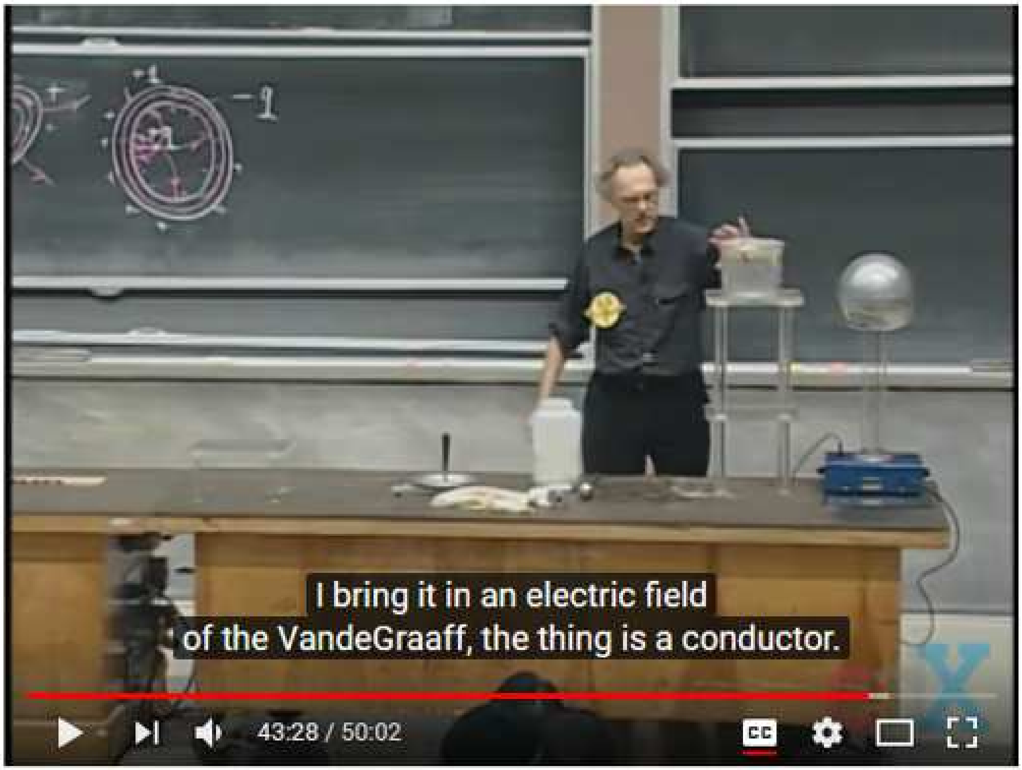
9. Induction of Conductor-II

Prof. Walter Lewin

The conductor is charged by the van de Graaff generator. Check the charge distribution

https://www.youtube.com/watch?v=JhV-GOS4y8g&index=7&list=PLyQSN7X0ro2314mKyUiOILaOC2hk6Pc3j&t=0s
43 minutes/50 minutes



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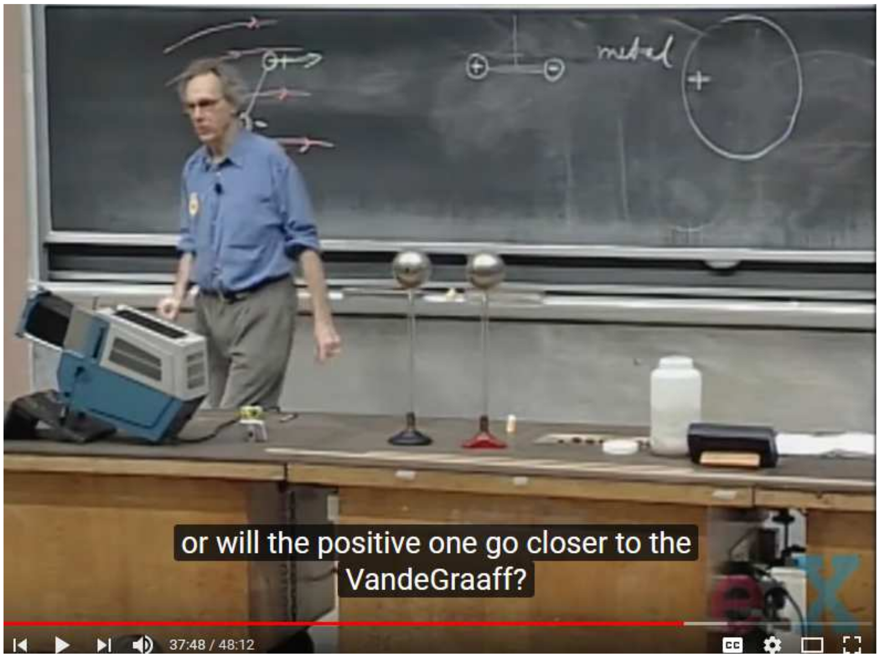
10. How does the van de Graaff generator work?

https://www.youtube.com/watch?v=vQCKwgTnhm4

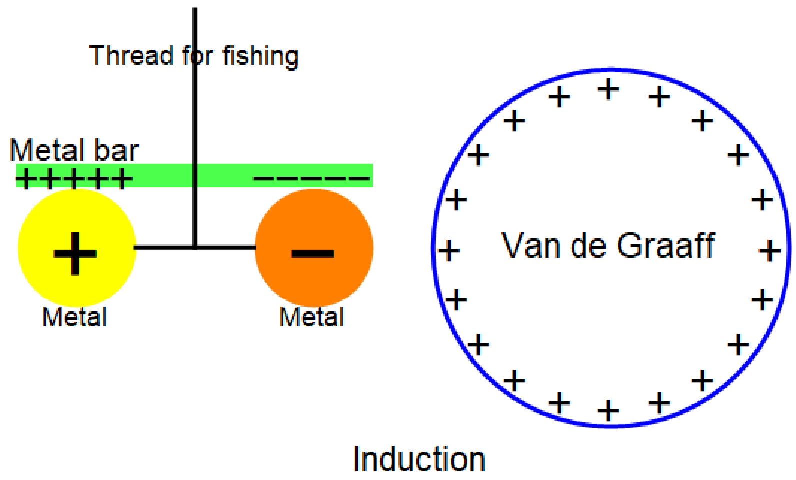
11. Electric dipole moment in the presence of Van der Graaff generator

Prof. Walter Lewin

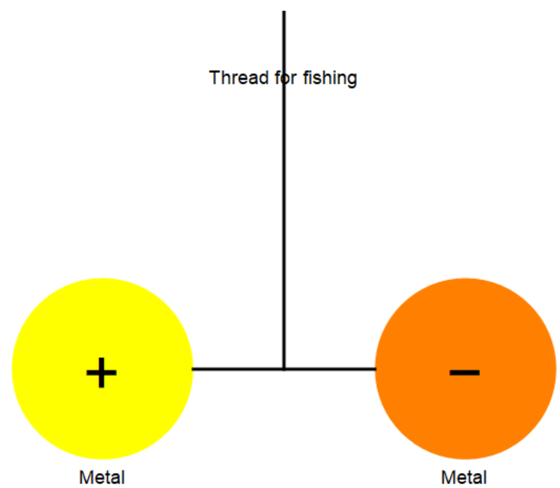
8.02x - Lect 2 - Electric Field Lines, Superposition, Inductive Charging, Induced Dipoles
https://www.youtube.com/watch?v=Pd9HY8iLiCA&index=4&t=0s&list=PLyQSN7X0ro2314mKyUiOILaOC2hk6Pc3j
37 minutes/50 minutyes



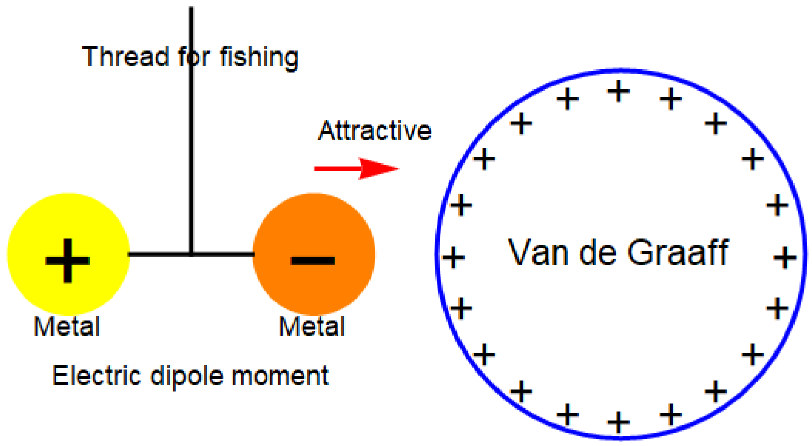
(a) Make an electric dipole moment using the Van de Graaff.



(b) Keep away from the Van de Graaff and remove the metal bar.



(c) Move the electric dipole moment wit the thread of fishing toward the Van de Graaff. There is an attractive force between the electric dipole moment and the Van de Graaff.



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12. Lightning and electric potential

Prof. Walter Lewin

Cooking pan: distribution of charge

LN-6

https://www.youtube.com/watch?v=ww0XJUqFHXU&list=PLyQSN7X0ro2314mKyUiOILaOC2hk6Pc3j&index=7

7.00 minitues/53.00 minutes

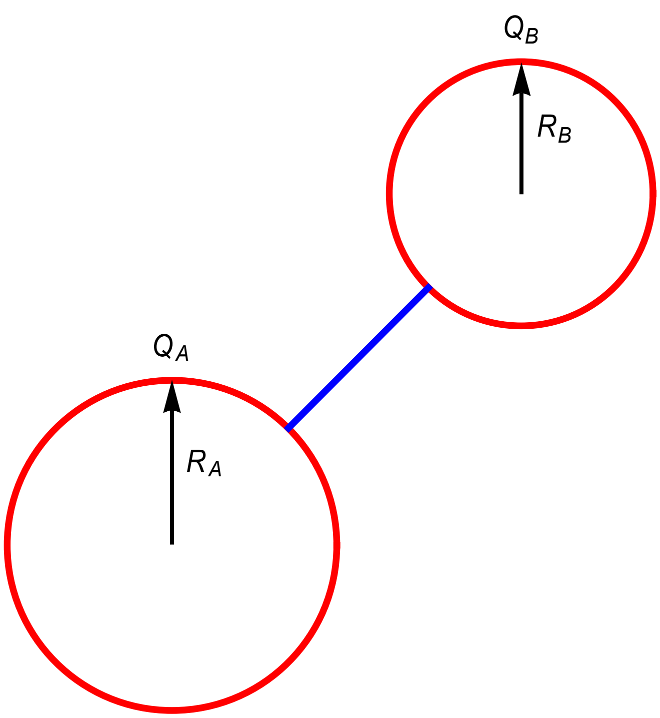


Fig.2 The field of a pointed object can be approximated by that of two spheres at the same potential.

The electric potential is the same when two spheres are connected with a wire,

$$\frac{Q_A}{4\pi\varepsilon_0 R_A} = \frac{Q_B}{4\pi\varepsilon_0 R_B},$$

or

$$\frac{Q_A R_A}{4\pi R_A^{\ 2}} = \frac{Q_B R_B}{4\pi R_B^{\ 2}},$$

or

$$R_A \sigma_A = R_B \sigma_B,$$

where

$$A_A = 4\pi R_A^{\ 2}, \qquad A_B = 4\pi R_B^{\ 2}.$$

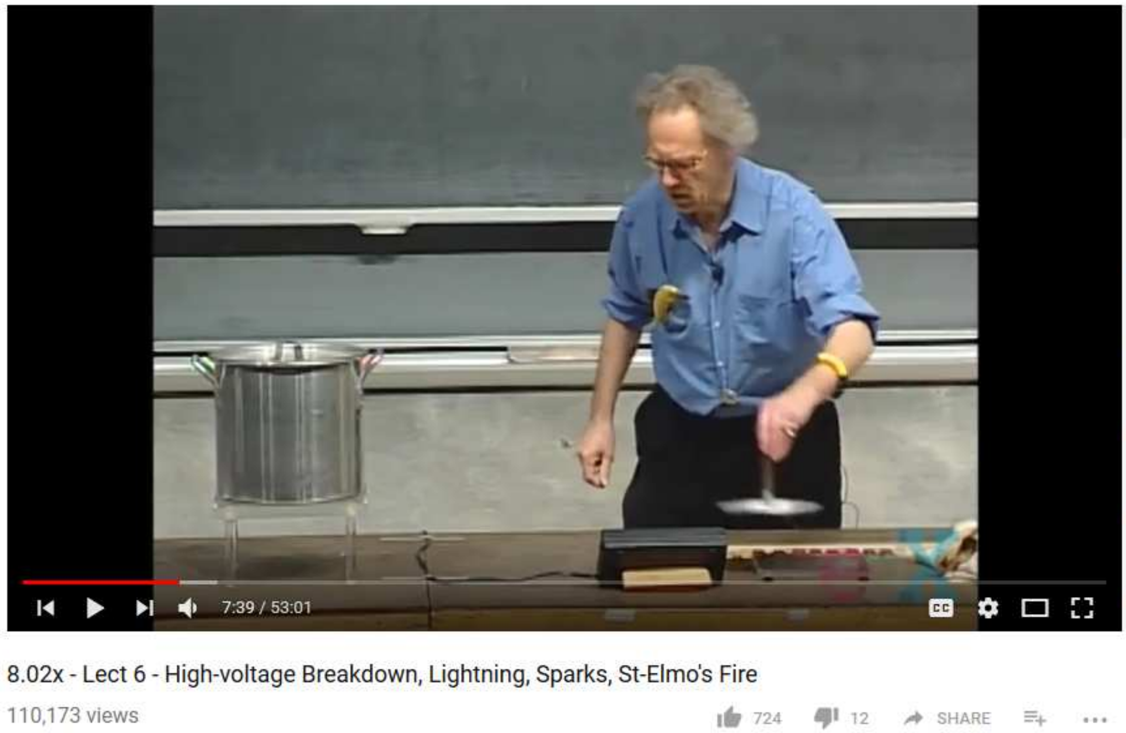
Noting that the electric field is

$$E_A = \frac{\sigma_A}{\varepsilon_0}, \qquad E_B = \frac{\sigma_B}{\varepsilon_0}.$$

we have

$$R_A E_A = R_B E_B.$$

Thus, the electric field becomes large when the radius of curvature becomes small.



((**Feynman**))

We would like now to discuss qualitatively some of the characteristics of the fields around conductors. If we charge a conductor that is not a sphere, but one that has on it a point or a very sharp end, as, for example, the object sketched in Fig., the field around the point is much higher than the field in the other regions. The reason is, qualitatively, that charges try to spread out as much as possible on the surface of a conductor, and the tip of a sharp point is as far away as it is possible to be from most of the surface. Some of the charges on the plate get pushed all the way to the tip. A relatively *small* amount of charge on the tip can still provide a large surface *density*; a high charge density means a high field just outside.

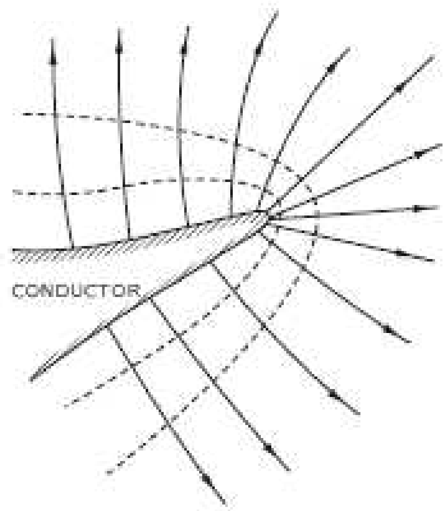


Fig.1 The electric field near a sharp point on a conductor is very high.

One way to see that the field is highest at those places on a conductor where the radius of curvature is smallest is to consider the combination of a big sphere and a little sphere connected by a wire, as shown in Fig.2 It is a somewhat idealized version of the conductor of **Fig.1**. The wire will have little influence on the fields outside; it is there to keep the spheres at the same potential. Now, which ball has the biggest field at its surface?

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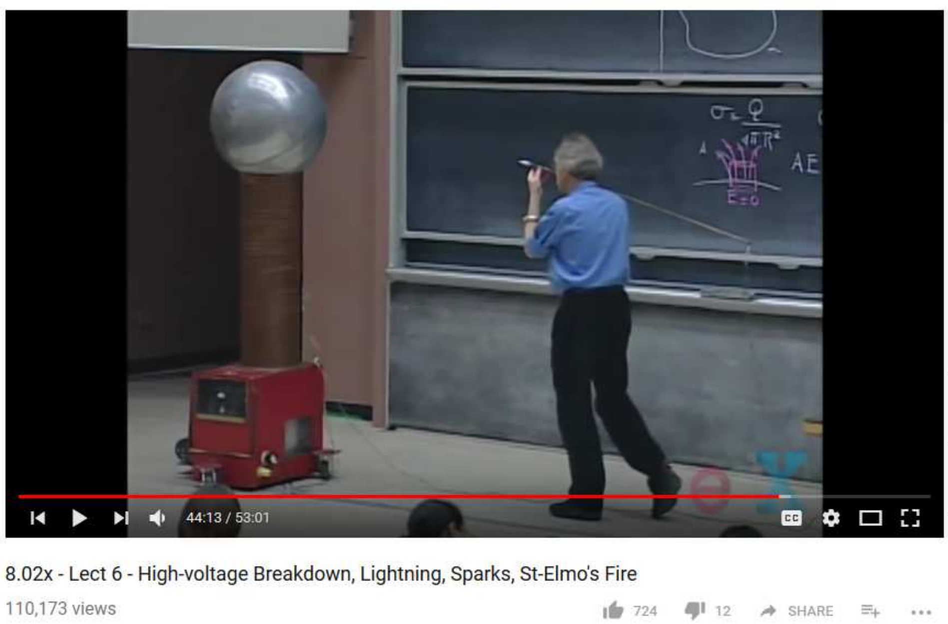
13. Sharp point close to van de Graaff

Prof. Walter Lewin

https://www.youtube.com/watch?v=ww0XJUqFHXU&list=PLyQSN7X0ro2314mKyUiOILaOC2hk6Pc3j&t=0s&index=8

42 minutes/53 minutes



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