GULU University February 2008

Course 105 ELECTRICITY and MAGNETISM

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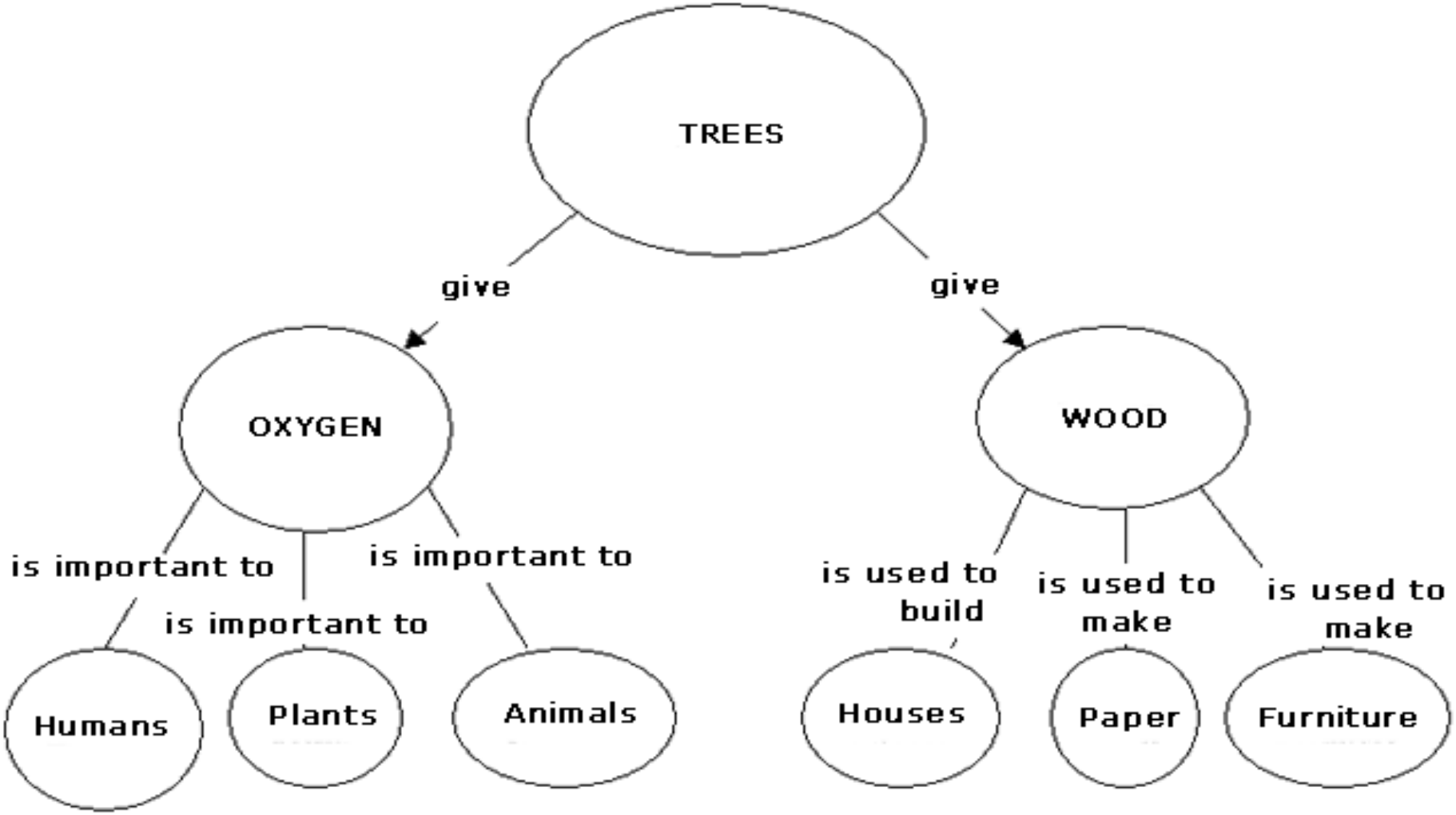
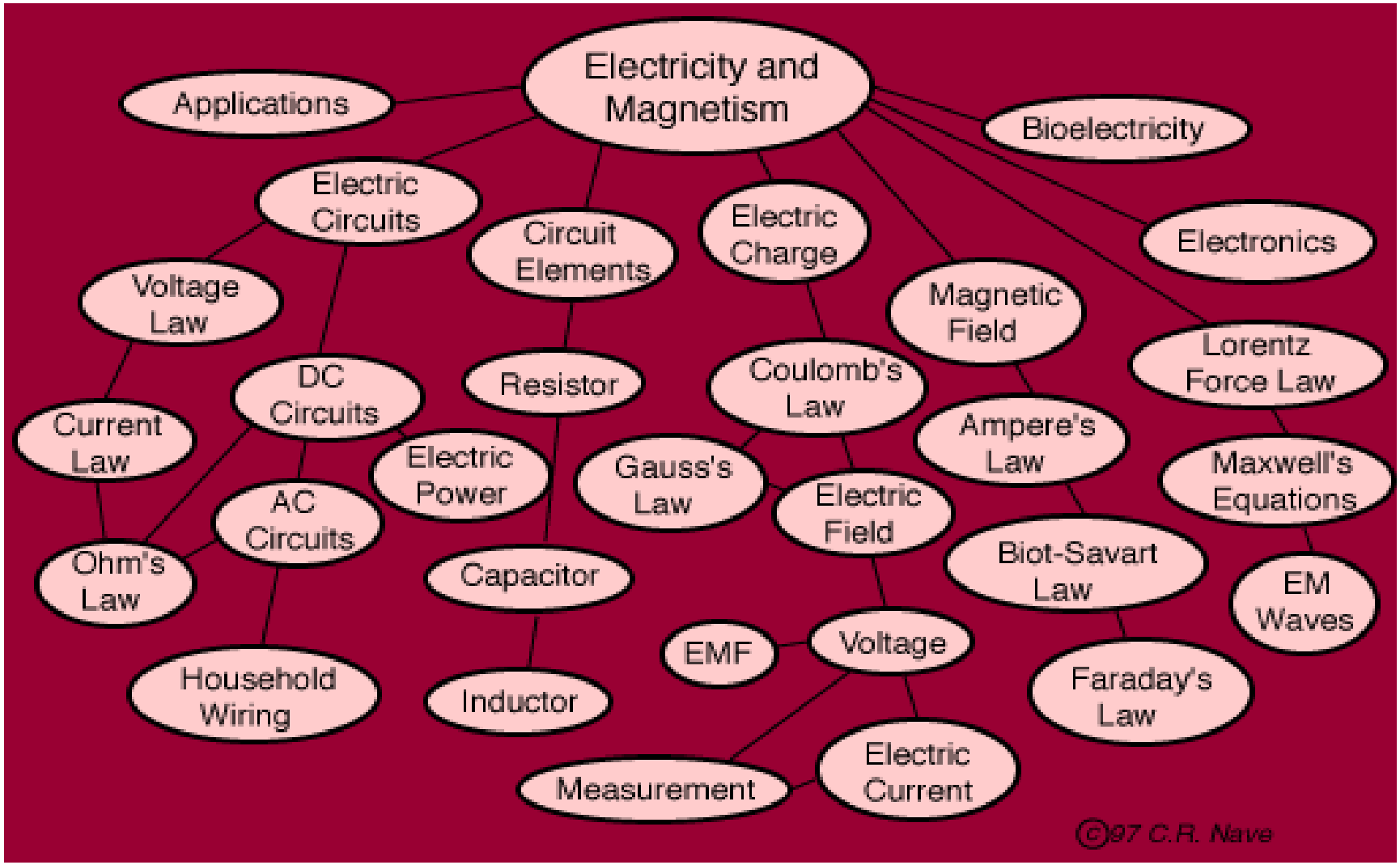
Concept mapping




Electricity and Magnetism
Applications
Bioelectricity
Electric Circuits
Circuit Elements
Electric Charge
Electronics
Voltage Law
Magnetic Field
Lorentz Force Law
DC Circuits
Resistor
Coulomb's Law
Current Law
Ampere's Law
Electric Power
Gauss's Law
Maxwell's Equations
AC Circuits
Electric Field
Biot-Savart Law
Ohm's Law
Capacitor
EM Waves
EMF
Voltage
Household Wiring
Inductor
Faraday's Law
Measurement
Electric Current
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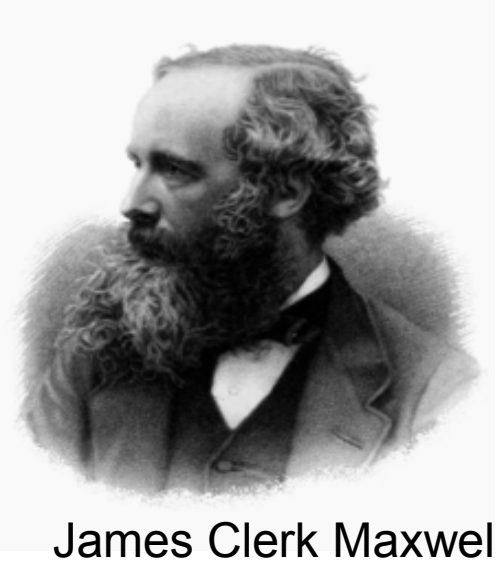
Some “fathers” of Electromagnetism

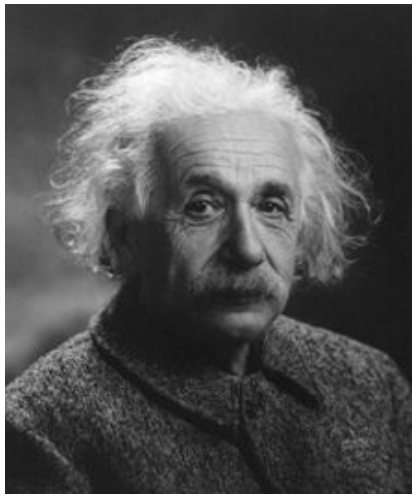
H. Christian Ørsted
(1777 - 1851)

André-Marie Ampère
(1775-1836)

Michael Faraday
(1791-1867)



James Clerk Maxwell
(1831 -1879)



Albert Einstein
(1879 -1955)

ELECTRICITY?

Ambiguous term from Physics viewpoint

ELECTRIC FIELD

ELECTRIC POTENTIAL

ELECTRIC CHARGE

ELECTRIC CURRENT

ELECTRIC ENERGY

ELECTRIC POWER

Electrostatics

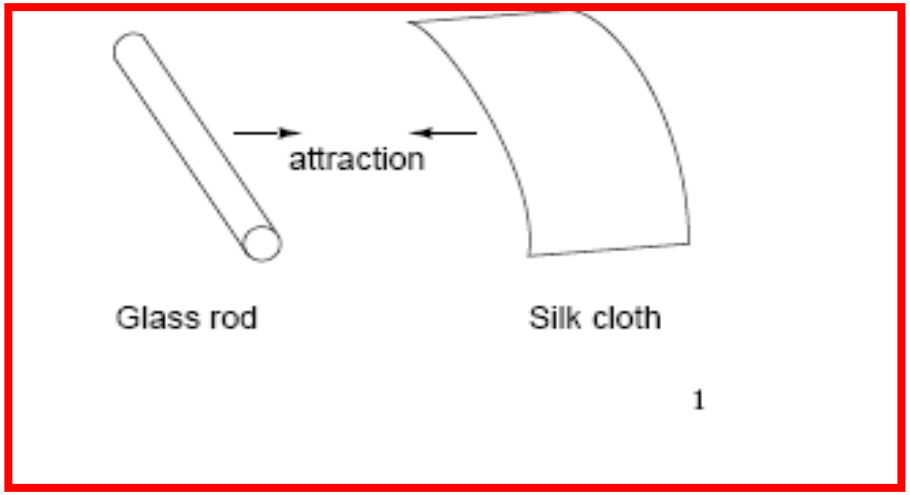
phenomena arising from stationary electric charges

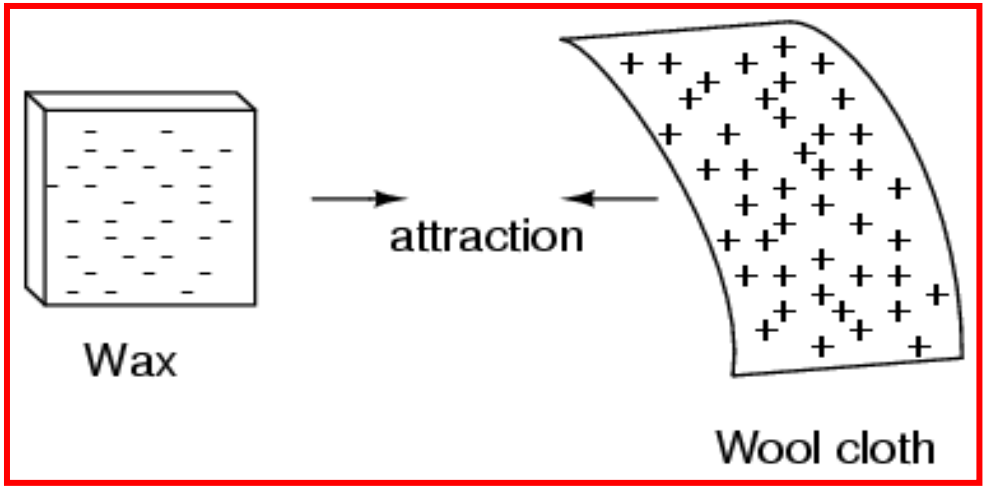
Some key ideas for Teaching Electrostatic

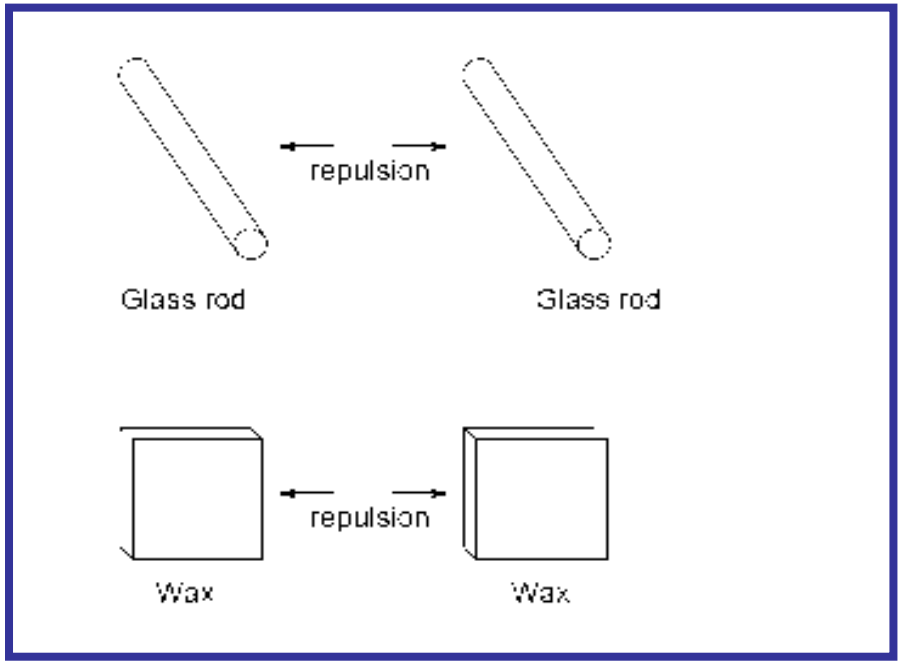
- Electrostatic in everyday life
- Attraction, repulsion, sparks
- Rubbing objects with wool cloth, human and animal hair
- Charge induction
- Imbalanced number of electrons and protons in an object
- Microscopic viewpoint
- ……

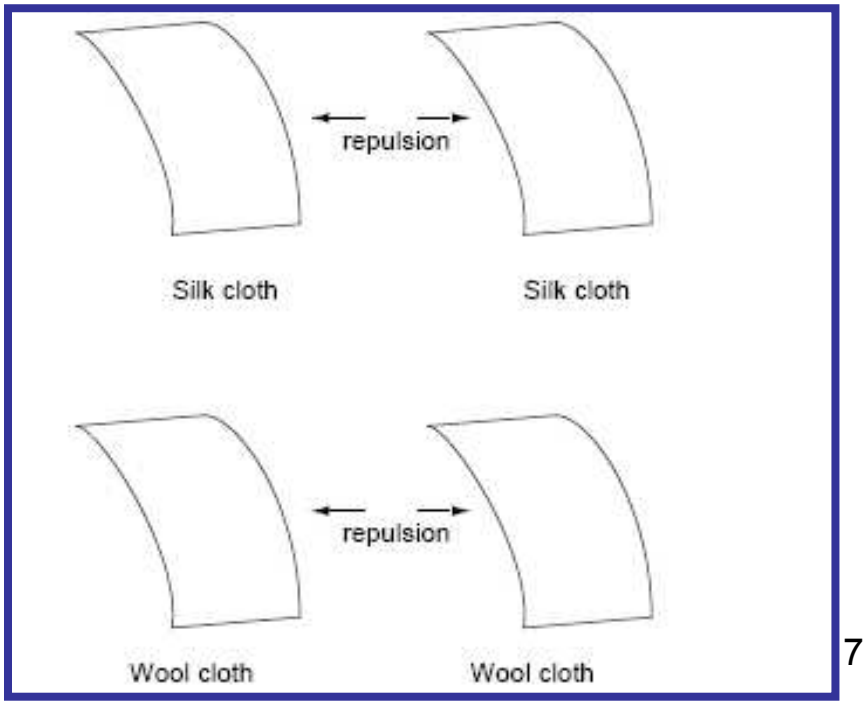
amber

Electrostatic phenomena: low cost experiments









Experimental demonstrations *best performed with very little relative humidity*

1) Jumping paper: small paper pieces attracted by a rubbed plastic pen

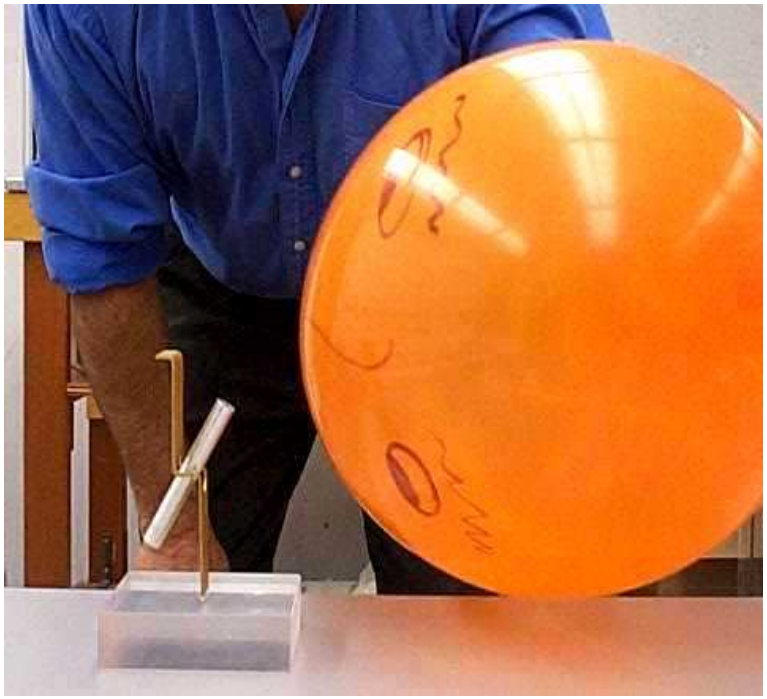
2) A balloon, rubbed on human hair, sticks on a wall

3) A rolling can: a soft drink can on its side is on a smooth surface. A large rubbed balloon is brought near the can that can roll towards it

ELECTROSTATIC DEMONSTRATIONS

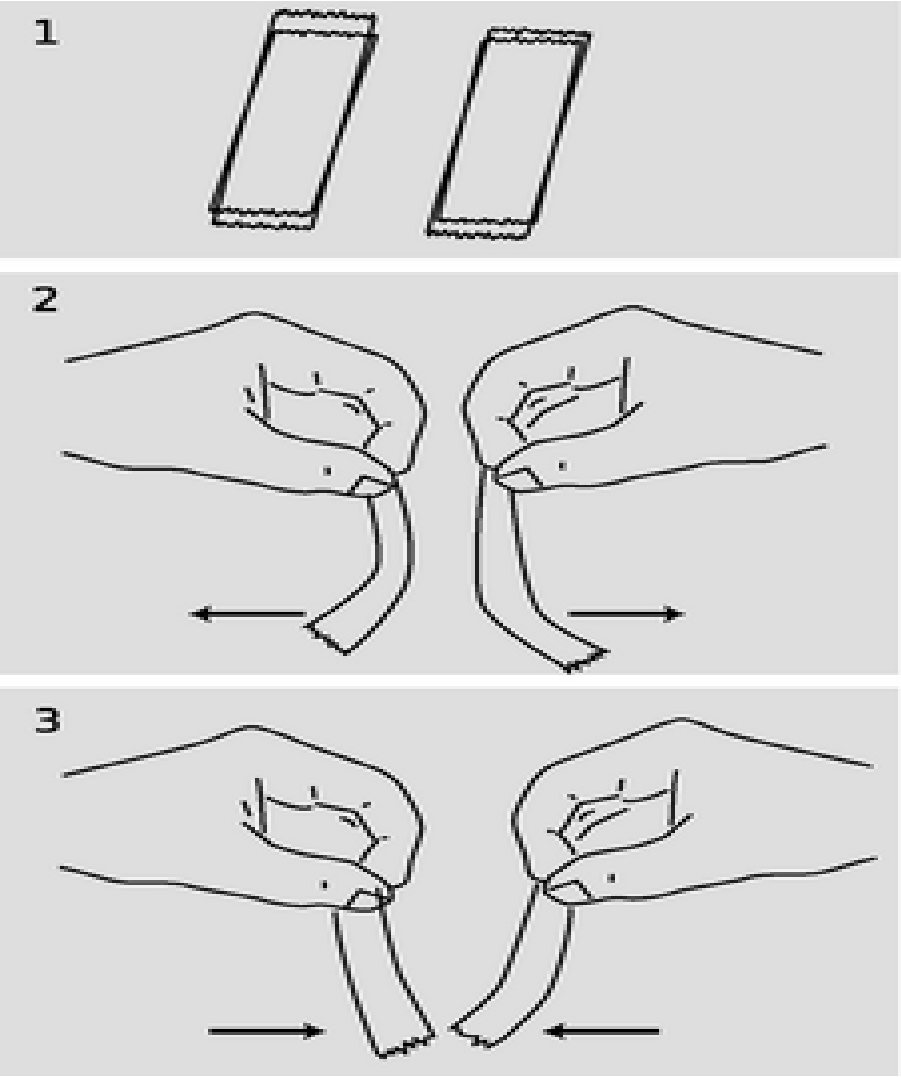
4) CHARGE METER A bent piece of brass is mounted on a plastic or wood base. An Al tube is placed in the appropriate slot in the brass. When charge is near, the Al tube bends towards the charged object

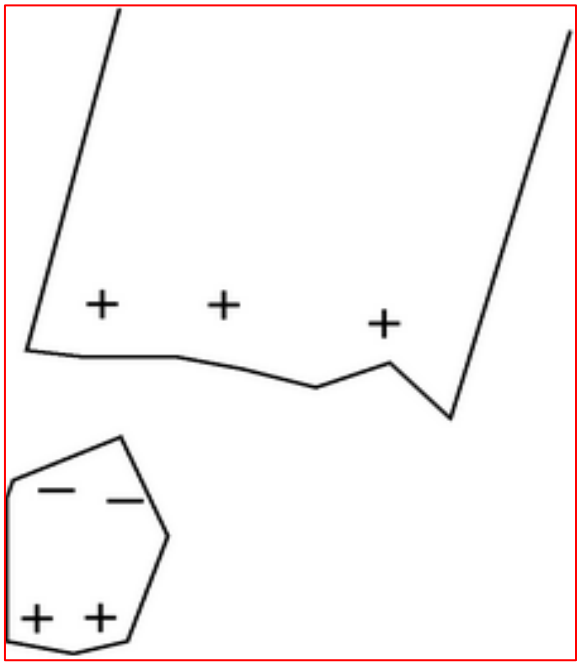
5) THE ADMIRER BALLOON Draw a face on an inflated balloon and suspend it at the level of your head. Rub the face of the balloon; it will move toward you whenever you approach it.



Tribo effect

4 Pieces of tape





TRIBOELECTRIC SERIES

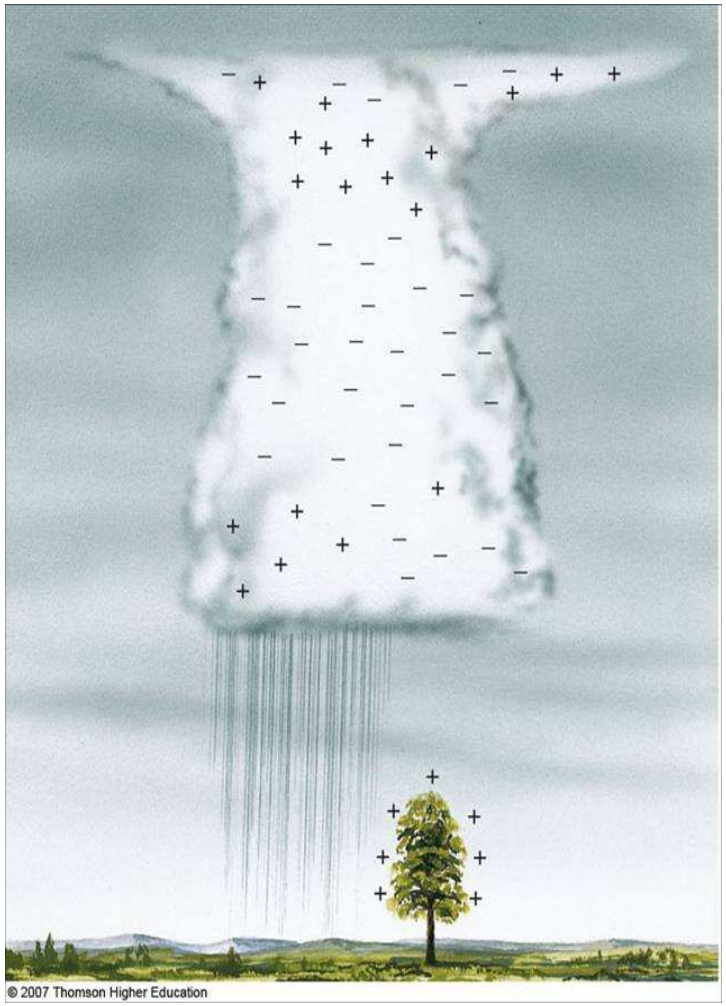
Most positively charged +	**Sealing wax**
	Rubber balloon
Human skin	**Resins**
Leather	**Hard rubber**
Rabbit's fur	**Rayon**
Glass	**Synthetic rubber**
Quartz	**Polyester**
Mica	**Styrofoam**
Human hair	**Plastic wrap**
Nylon	**Polyethylene (like Scotch tape)**
Wool	**PolypropyleneVinyl (PVC)**
Cat's fur	**Silicon**
Silk	**Teflon**
Aluminium	**Ebonite**
Paper (*Small* + *charge*)	
Cotton (No *charge*)	***Most negatively charged -***
Wood (*Small charge*)	
Amber	

How many types of charge?

Positive and negative

Point-like Electric charge: an idealized model of a charged particle
It is an electric charge at a mathematical point with no dimensions

Approximation
the dimension of the charged objects are much smaller than the other distances involved



Electron mass = 9.1095×10^{-31} kg

Electron charge = 1.602×10^{-19} coulomb

Electron radius = 2.8179×10^{-13} cm

How do point-like charges interact?

$$F = k\, q_1\, q_2 (1/r^2)\, r$$

F = electrostatic force, k = Coulomb's constant

q_1, q_2 = first and second charge

r = distance between the two charges

F is a vector, like all forces

Direction = segment connecting the charges

F = Attractive if charges of same sign

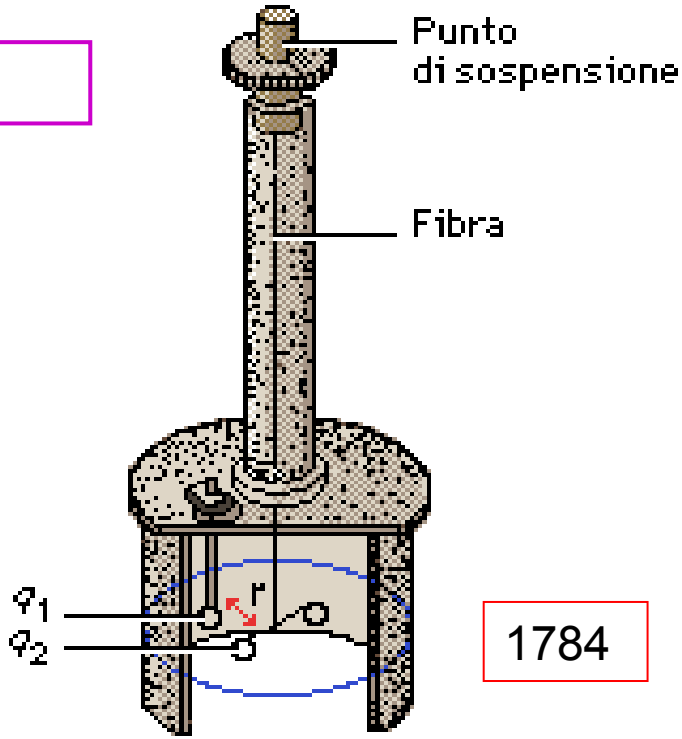
F = Repulsive if charges of opposite sign

Dimension of a Force = m l t^{-2}

Unit = Netwon = kg meter $second^{-2}$

Unit of charge = Coulomb =

6.24×10^{18} charge of an electron



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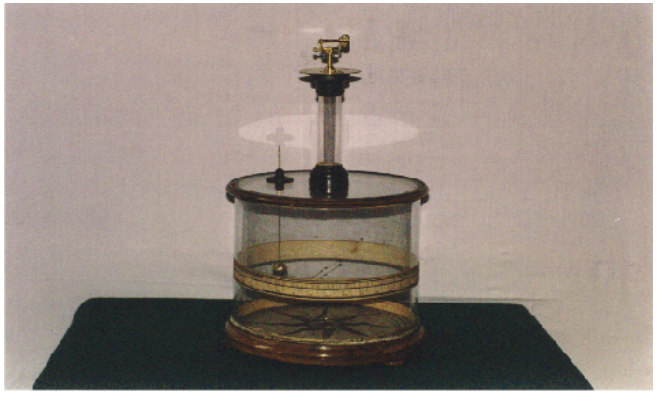
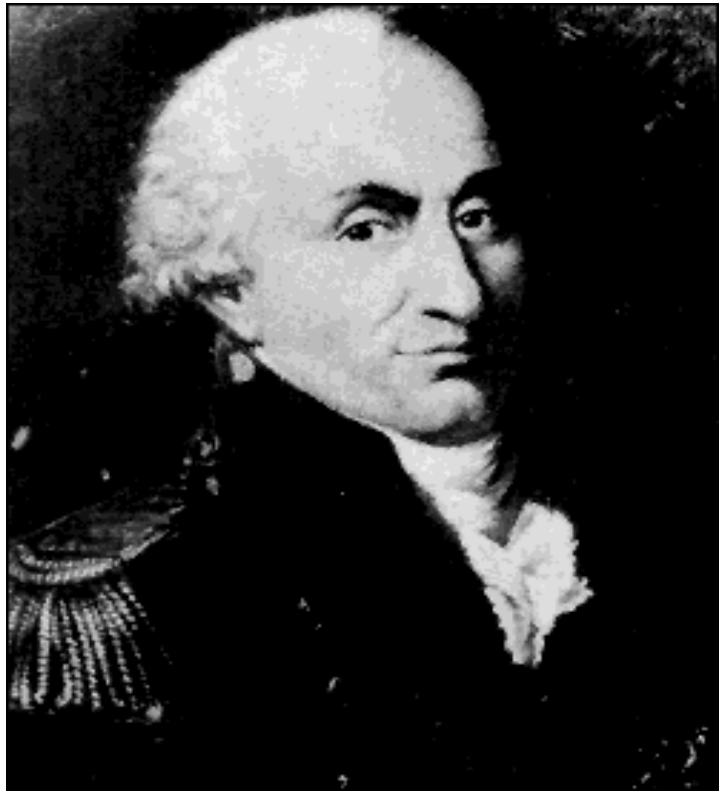
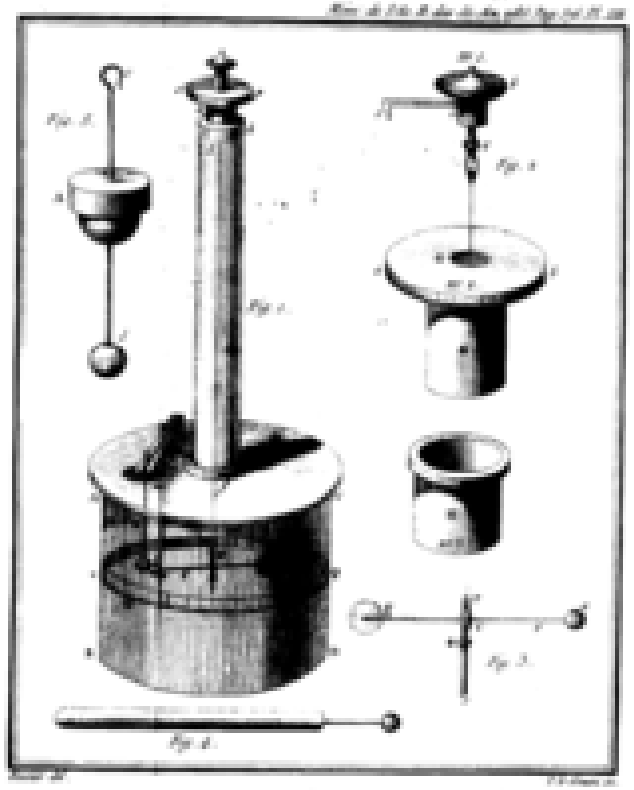


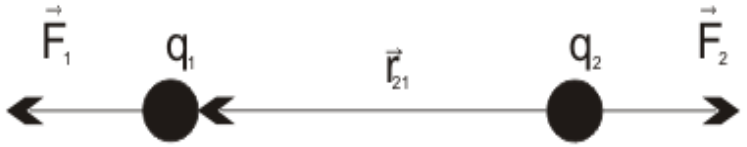
Torsion Balance

Electrostatic Force: Coulomb's Law





$$\mathbf{F} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2(\mathbf{r}_1 - \mathbf{r}_2)}{|\mathbf{r}_1 - \mathbf{r}_2|^3} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}\hat{\mathbf{r}}_{21}$$



$$k_C = \frac{1}{4\pi\varepsilon_0} \approx 8.988 \times 10^9$$

N m^2 C^{-2}

Parallels between electrostatics and gravity

$$\mathbf{F} = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}\hat{\mathbf{r}} = q\mathbf{E}$$

$$\mathbf{F} = G\frac{Mm}{r^2}\hat{\mathbf{r}} = m\mathbf{g}$$

Central and Conservative forces

Inverse-square dependence from distance

No negative mass

Some “fathers” of Electricity

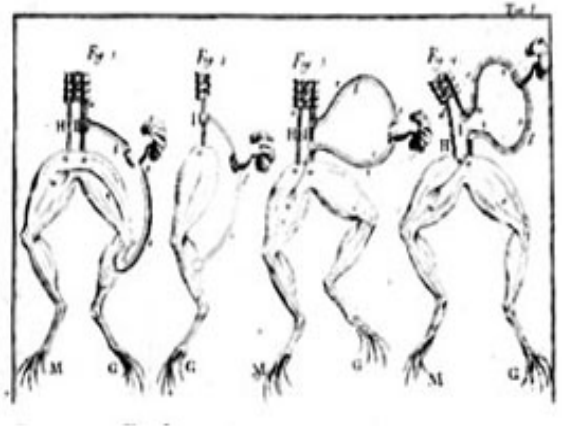
Boyle R.

Franklin B.

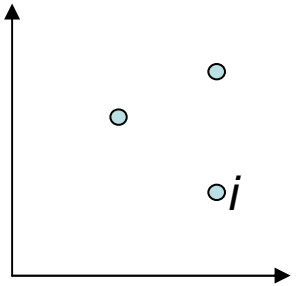
Volta A.

Faraday M.

Galvani L.



What happens when there are N point-like charges?



$$\mathbf{F}(\mathbf{r}) = \frac{q}{4\pi\varepsilon_0}\sum_{i=1}^{N}\frac{q_i(\mathbf{r}-\mathbf{r}_i)}{|\mathbf{r}-\mathbf{r}_i|^3} = \frac{q}{4\pi\varepsilon_0}\sum_{i=1}^{N}\frac{q_i}{R_i^2}\hat{\mathbf{R}}_i$$

q_i and r_i = magnitude and position of the i_{th} charge

$\hat{\mathbf{R}}_i$ s a unit vector pointing from charge q_i to the test charge q

$\mathbf{R}_i = \mathbf{r} - \mathbf{r}_i$ its magnitude R_i is the distance between charges qi and q

Linear Superposition