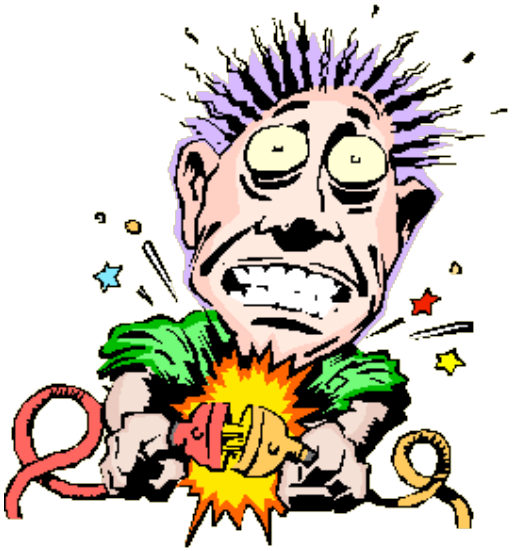
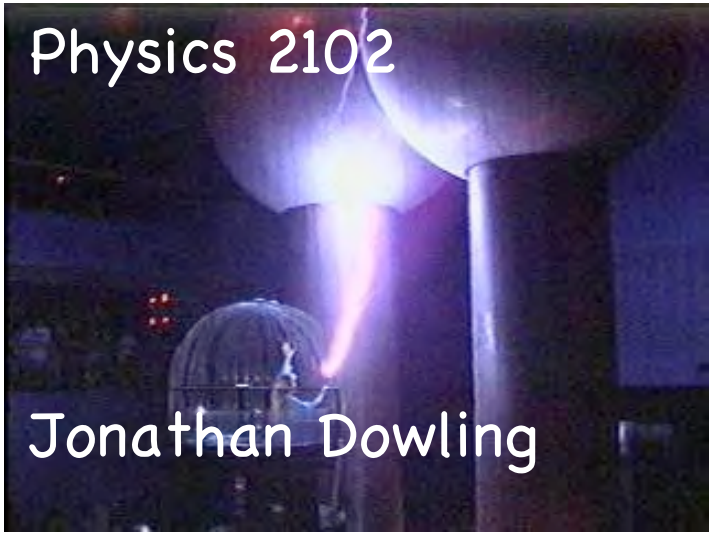




Benjamin Franklin
(1705–1790)

Physics 2102
Lecture 01: TUE 19 JAN

Electric Charge

Charles-Augustin
de Coulomb
(1736–1806)

Who am I & Why am I Here?

Prof. J. P. Dowling

1994–98: Research Physicist, US Army Aviation & Missile Command
1998–2004: Principal Scientist, NASA Jet Propulsion Laboratory
2004–Present: Director, Hearne Institute for Theoretical Physics, LSU

Office hours: Nicholson Hall 453,
12:00N–1:00PM TTh (or by appointment)

Email: jdowling@lsu.edu

Hearne Institute for Theoretical Physics
Quantum Sciences & Technologies Group

My Own Research:

Quantum Technologies
Photonics

Course Details

- Main **Class Website for All Sections:**
http://www.phys.lsu.edu/classes/spring2010/phys2102/
Syllabus, Schedule, Grading Policy, Exam Solutions, …

- **Lectures** will be posted in this section's website:
http://phys.lsu.edu/~jdowling/PHYS21024SP10/

- **Text:** Fundamentals of Physics, Halliday, Resnick, and Walker, 8th edition. We will cover Chapters 21-33,35-36,38.

- **Exams:** Midterms 6-7PM: THU **11 FEB, THU 11 MAR, THU 15 APR;** Final Exam 7:30-9:30AM TUE 11 MAY 2010.

- **Lab: Meets This Week! Show up or be dropped!**

- **Tutoring:** ***Free Tutors*** **in 102 Nicholson & 141 Middleton:**
http://cas.lsu.edu/tutorial-centers

Course Details: Homework

Web-based system: Web Assign

To register:

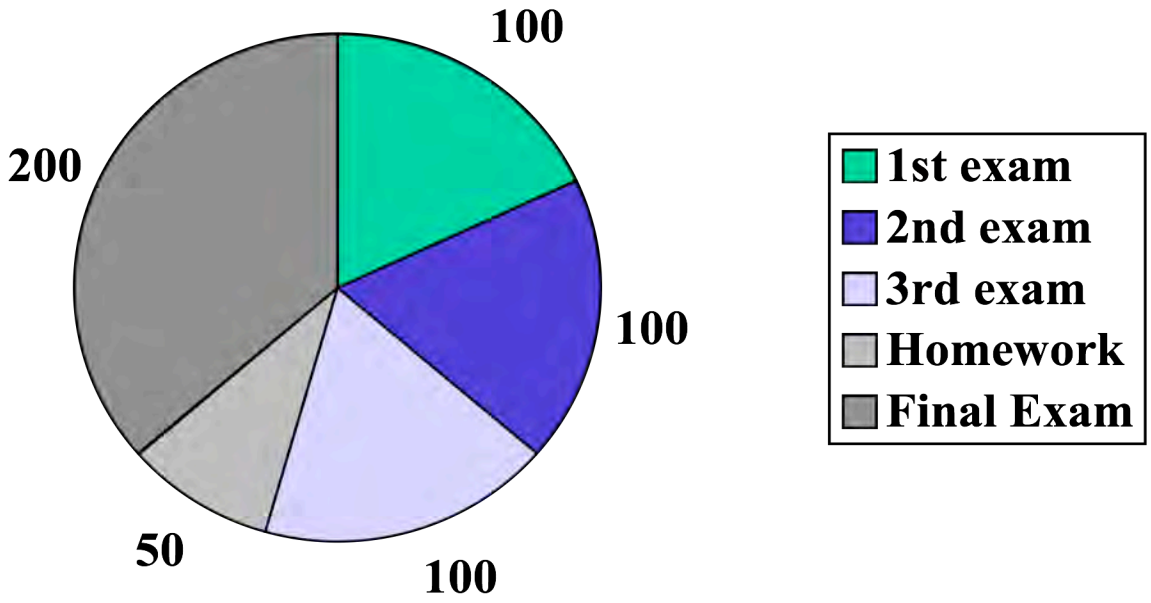
- Go to **http://www.webassign.net/student.html**
- On the left frame, "student login"
  - *Username*: pawsusername@lsu
  - *Institution*: lsu
  - *Password*: lsuidnumber

- Choose "credit card registration" ($$$) or FREE with Purchase of PHYS2102 Book from Bookstore

- One Assignment Per Week Due 2AM Wednesdays.

- First HW Is Posted This Week Due Next WED 2AM.

Course Details: Grading



A: ≥90 B: 80-89 C: 60-79 D: 50-59 F: <50

Borderline Cases Decided by Class Attendance Checkmarks!

What Are We Going to Learn? A Roadmap!

- Electric *Charge*
  & Electric *Force* on Other Electric Charges
  & Electric *Field*, and Electric *Potential*
- Moving Electric Charges: Current
- Electronic Circuit Components: Batteries, Resistors, Capacitors
- Electric Currents & Magnetic Field
  & Magnetic Force on Moving Charges
- Time-Varying Magnetic Field & Electric Field
- More Circuit Components: Inductors, AC Circuits.
- Maxwell's Equations & Electromagnetic Waves & Light Waves
- Physical Optics (Light Waves): Interference, Diffraction.
- Quantum Physics!

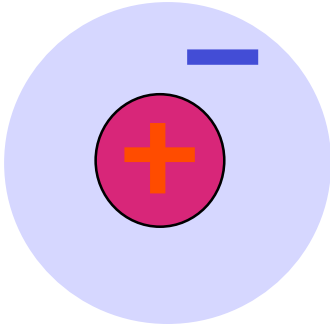
Let's Get Started! Electric Charges...

- Two Types of Charges: Positive/Negative
- Like Charges Repel
- Opposite Charges Attract

Atomic Structure:

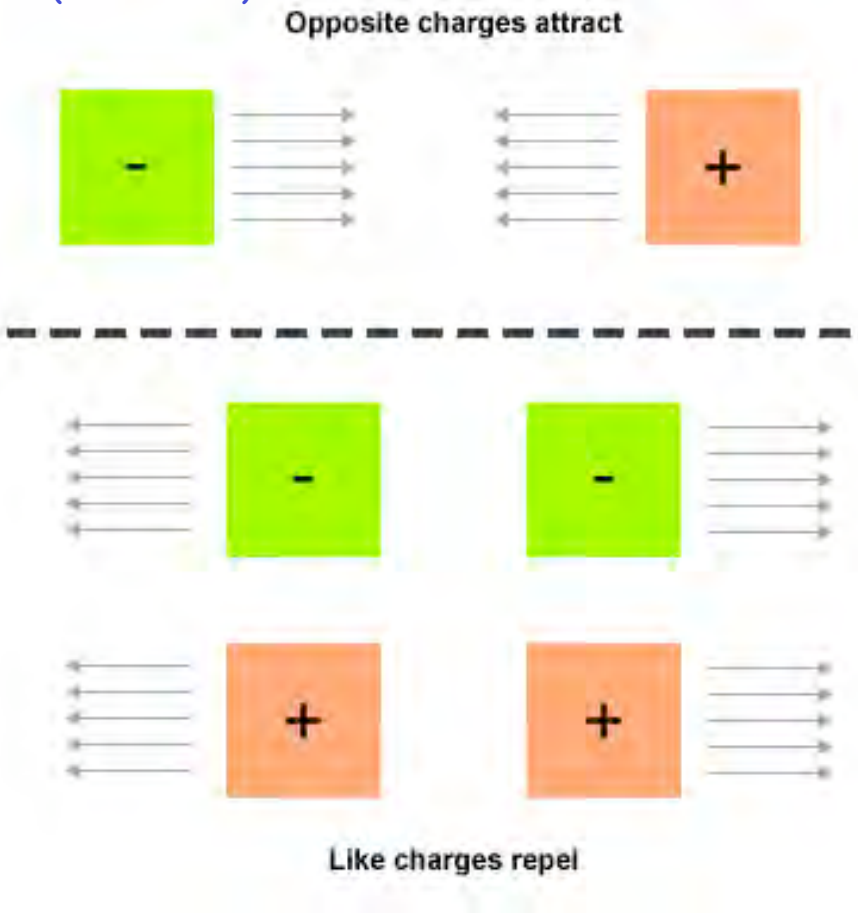
- Negative Electron Cloud
- Nucleus of Positive Protons, Uncharged Neutrons

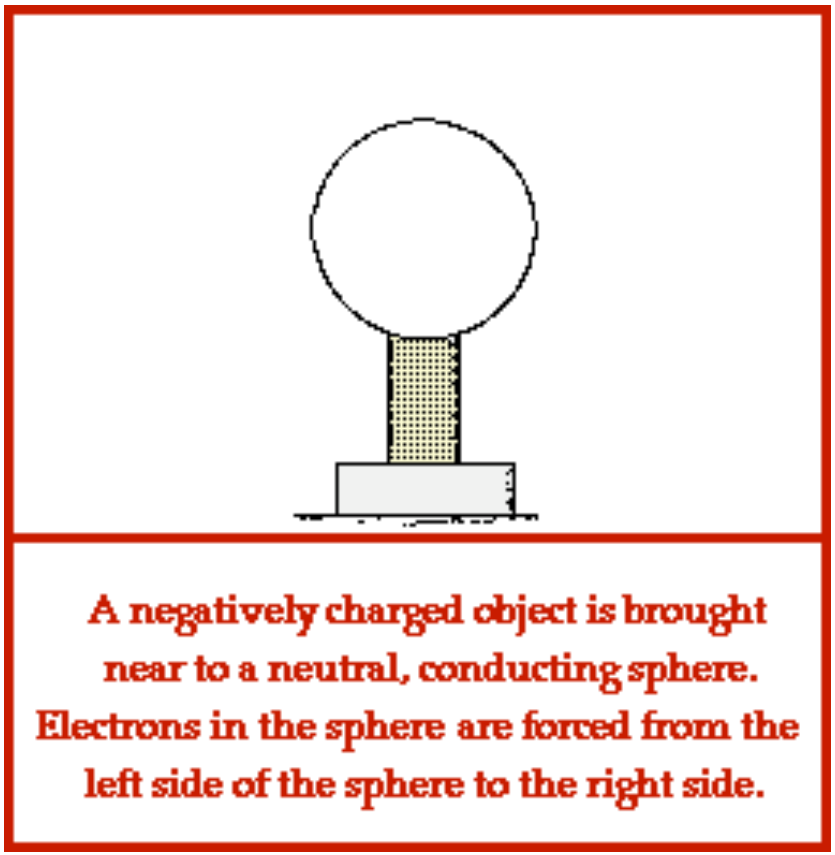
The Unit of Electric Charge is the "Coulomb" which is "C".
Proton Charge: $e = 1.60 \times 10^{-19}$ C



Benjamin Franklin
(1705–1790)

Rules of Electric Attraction and Repulsion Discovered by Benjamin Franklin

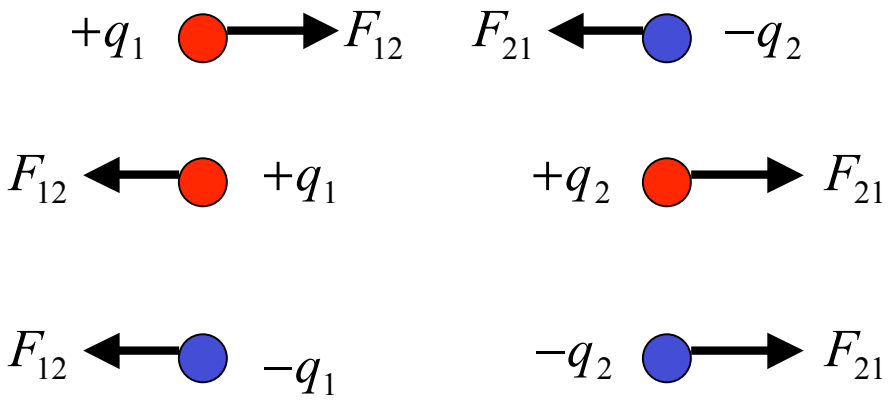




A negatively charged object is brought near to a neutral, conducting sphere. Electrons in the sphere are forced from the left side of the sphere to the right side.

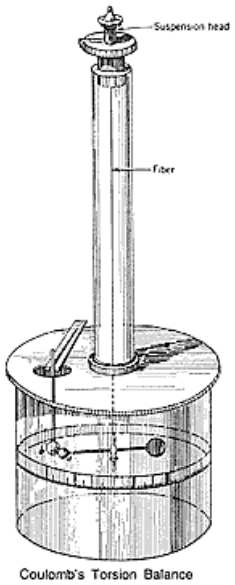
Force Between Pairs of Point Charges: Coulomb's Law

Charles-Augustin
De Coulomb
(1736–1806)



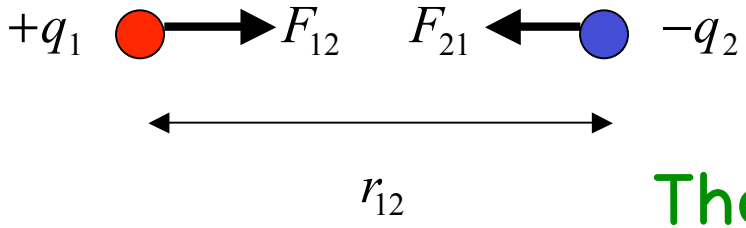
Coulomb's Law — the Force Between Point Charges:

- Lies Along the Line Connecting the Charges.
- Is Proportional to the Product of the Magnitudes.
- Is Inversely Proportional to the Distance Squared.
- Note That Newton's Third Law Says $|F_{12}| = |F_{21}|$!!



Coulomb's Torsion Balance

Coulomb's Law



The "k" is the electric constant of proportionality.

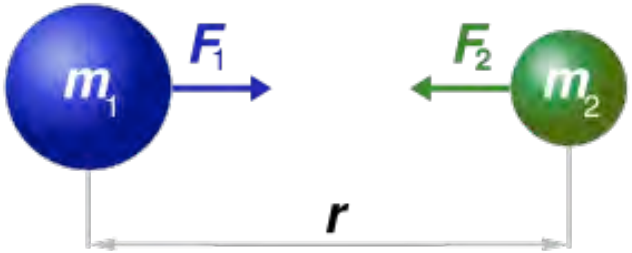
$$|F_{12}| = \frac{k\ |q_1|\ |q_2|}{r_{12}^2}$$

$$k = 8.99 \times 10^9\ \frac{\mathrm{N\,m^2}}{\mathrm{C^2}}$$

Usually, we write: $k = {}^{1}\!/_{4\pi\varepsilon_0}$ with $\varepsilon_0 = 8.85 \times 10^{-12}\ \frac{\mathrm{C^2}}{\mathrm{N\,m^2}}$

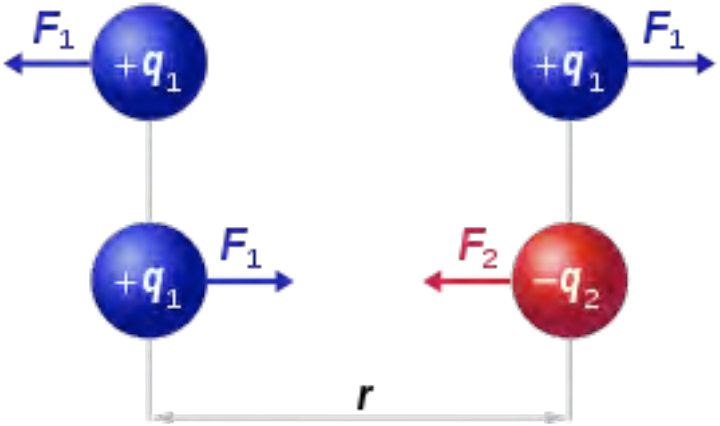
Units: F = [N] = [Newton]; r = [m] = [meter]; q = [C] = [Coulomb]

Two Inverse Square Laws



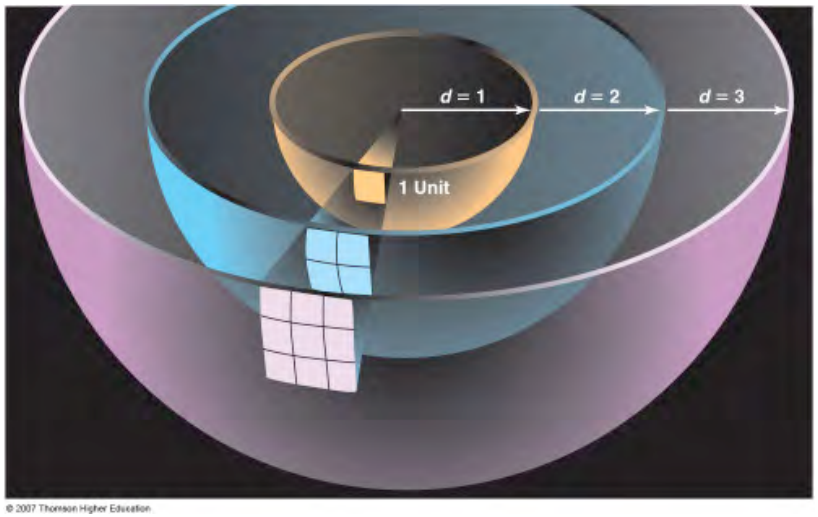
$$F_1 = F_2 = G\frac{m_1 \times m_2}{r^2}$$

Newton's Law of Gravitational Force



$$F_1 = F_2 = k_c\frac{q_1 \times q_2}{r^2}$$

Coulomb's Law of Electrical Force



Area of Sphere = $4\pi r^2$

Number of Lines of Force is Constant.

Hence Force Per-Unit-Area is Proportional to $1/r^2$

Superposition

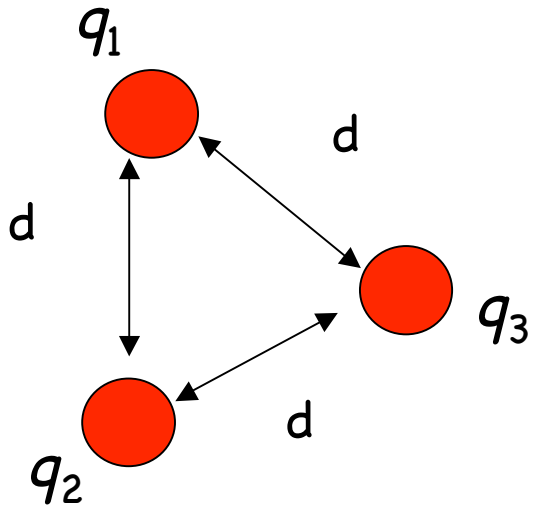
- **Question**: How Do We Figure Out the Force on a Point Charge Due to Many Other Point Charges?
- **Answer**: Consider One Pair at a Time, Calculate the Force (a Vector!) In Each Case Using Coulomb's Law and Finally Add All the Vectors! ("Superposition")
- Useful To Look Out for SYMMETRY to Simplify Calculations!

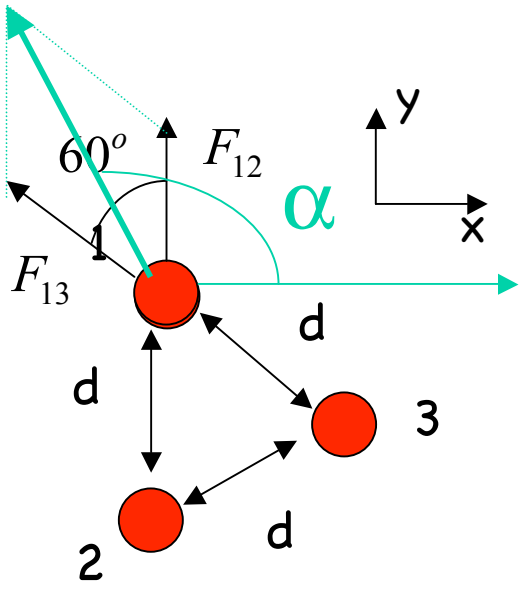
Feel the Force! Example

$q_1 = q_2 = q_3 = 20$ mC

- Three Equal Charges Form an Equilateral Triangle of Side 1.5 m as Shown
- Compute the Force on q_1
- What are the Forces on the Other Charges?

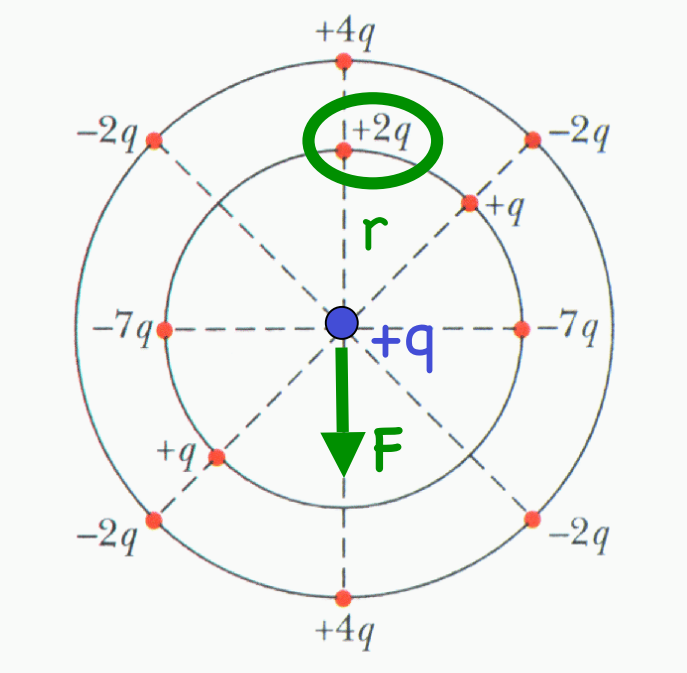
Solution: Set up a Coordinate System, Compute Vector Sum of F_{12} and F_{13}





Another Example With Symmetry

$$\left|\vec{F}\right| = \frac{k\ \left|+2q\right|\ \left|+q\right|}{r^2}$$



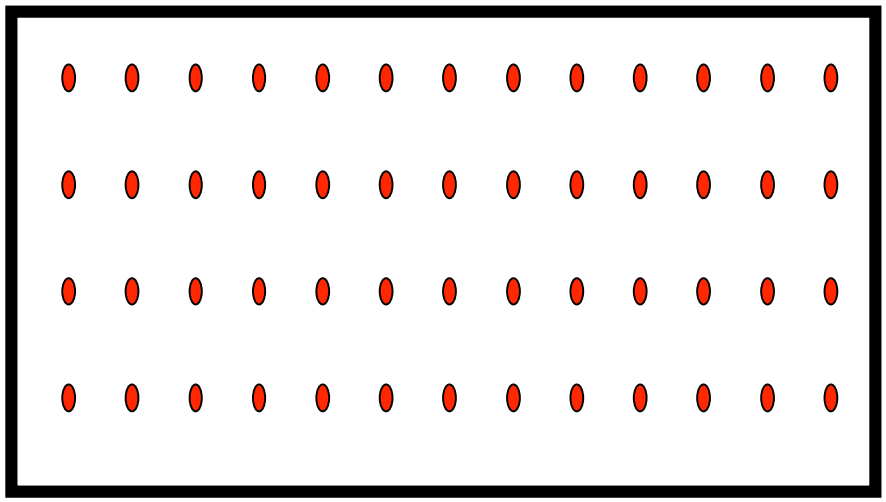
Charge +q
Placed at Center

What is the Force on Central Particle?

All Forces Cancel Except From +2q!

Electric Charges in Solids

- In Macroscopic Solids, Nuclei Often Arrange Themselves Into a Stiff Regular Pattern Called a "Crystal Lattice".



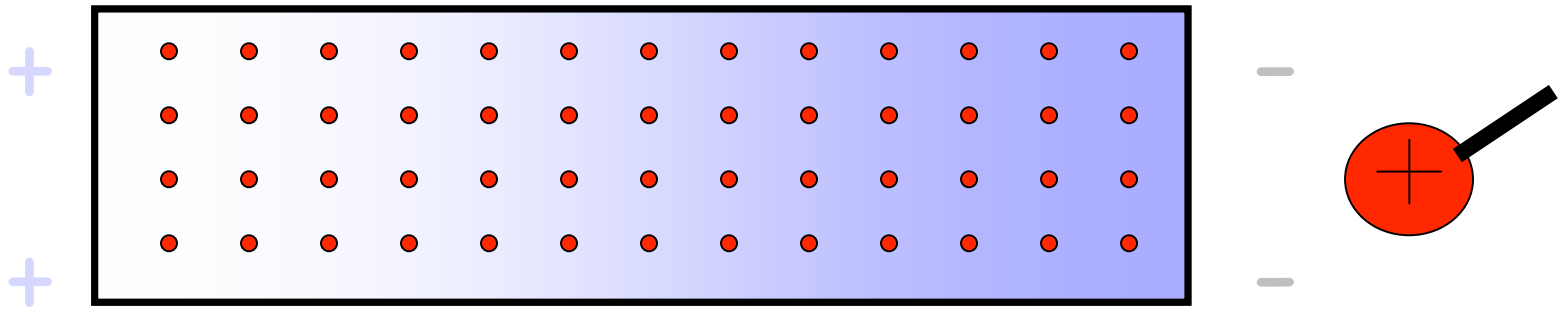
- Electrons Move Around This Lattice. Depending on How They Move the Solid Can Be Classified by Its "Electrical Properties" As an Insulator or a Conductor.

Charges in Solids

- In a Conductor, Electrons Move Around Freely, Forming a "Sea" of Electrons. This Is Why Metals Conduct Electricity.
- Charges Can Be "Induced" (Moved Around) in Conductors.

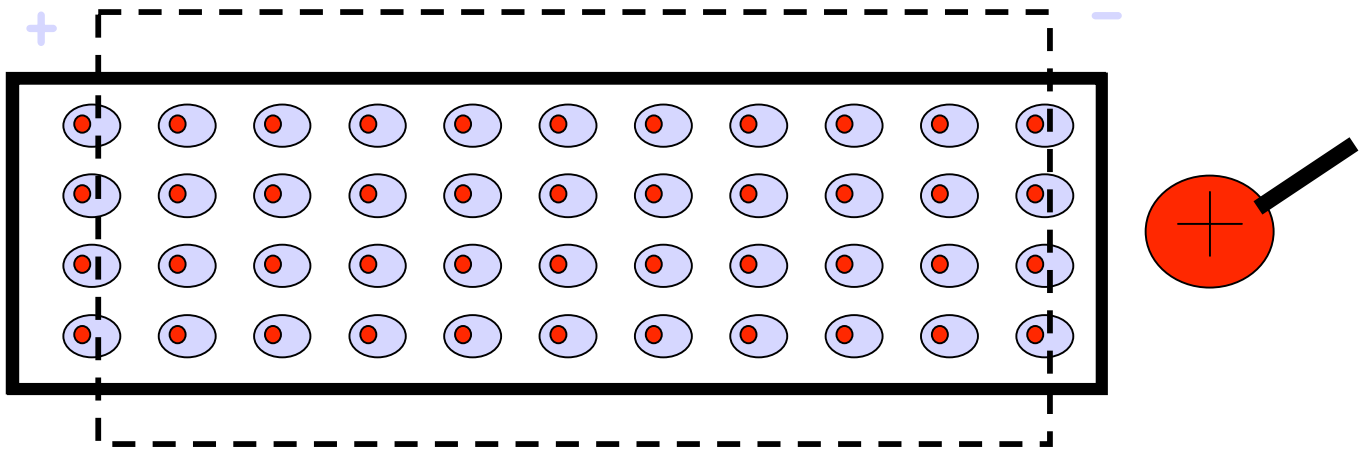
Blue Background = Mobile Electrons

Red Circles = Static Positive Charge (Nuclei)



Insulating Solids

- In an Insulator, Each Electron Cloud Is Tightly Bound to the Protons in a Nucleus. Wood, Glass, Rubber.
- Note That the Electrons Are Not Free to Move Throughout the Lattice, but the Electron Cloud Can "Distort" Locally.



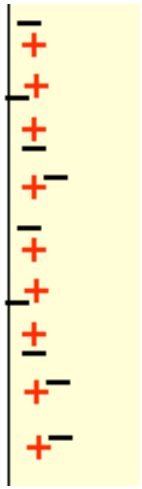
How to Charge an Object

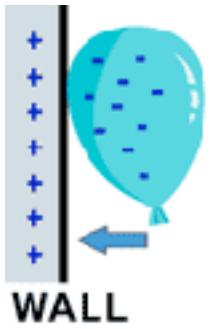
- An Object Can Be Given Some "Excess" Charge: Giving Electrons to It (We Give It Negative Charge) or Taking Electrons Away (We "Give" It Positive Charge).

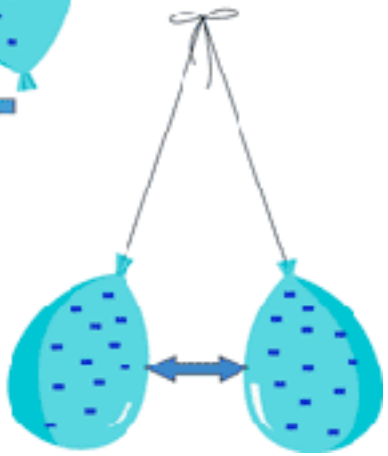
- How Do We Do Charge an Object? Usually, Moving Charges From One Surface to Another by Adhesion (Helped by Friction), or by Contact With Other Charged Objects.

- If a Conductor, the Whole Electron Sea Redistributes Itself.

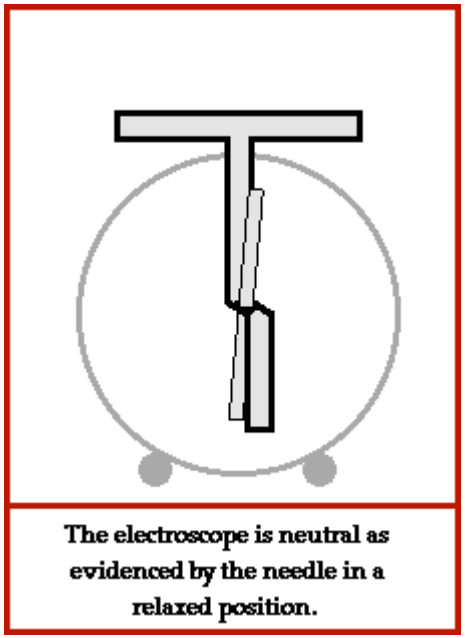
- If an Insulator, the Electrons Stay Where They Are Put.







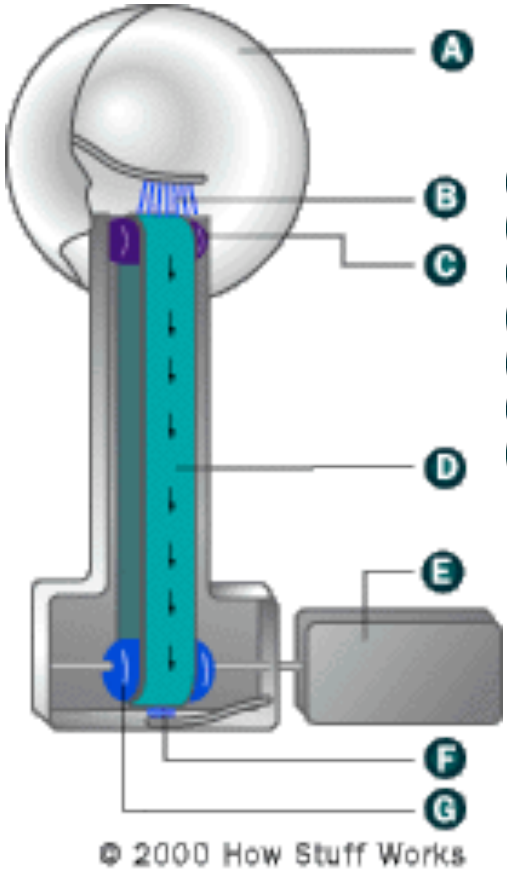
Electroscope



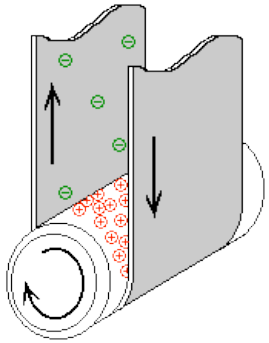
The electroscope is neutral as evidenced by the needle in a relaxed position.

http://www.physicsclassroom.com/mmedia/estatics/esn.html

Van der Graaf Generator



A Output terminal — An aluminum or steel sphere
B Upper brush — A piece of fine metal wire
C Upper roller — A piece of nylon
D Belt — A piece of surgical tubing
E Motor
F Lower brush
G Lower roller — A piece of nylon covered with silicon tape



http://science.howstuffworks.com/vdg2.htm

http://www.amasci.com/emotor/vdg.html

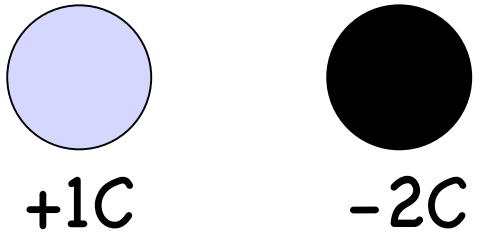

AΨΒ

Conservation of Charge

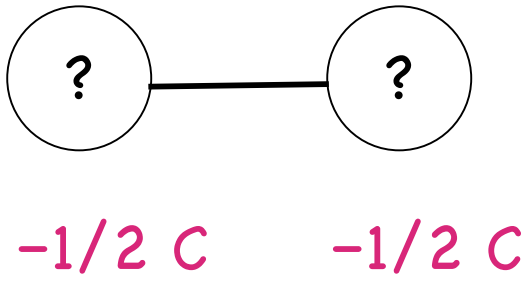
Total Amount of Charge in an Isolated System Is Fixed ("Conserved")

Example: 2 Identical Metal Spheres Have Charges

+1C and −2C.



You connect these together with a metal wire; what is the final charge distribution?



Quantization of Charge

- Charge is always found in **INTEGER** multiples of the charge on an electron/proton.
- Unit of charge: Coulomb (C) in SI units
- Electron charge = $-e$ = -1.6 x 10^{-19} Coulombs
- Proton charge = $+e$ = +1.6 x 10^{-19} Coulombs
- One cannot ISOLATE FRACTIONAL CHARGE (e.g. -1/2 e, +1/3 e, etc.)

Ch. 21: Summary

- Electric Charges Come With Two Signs: Positive and Negative.

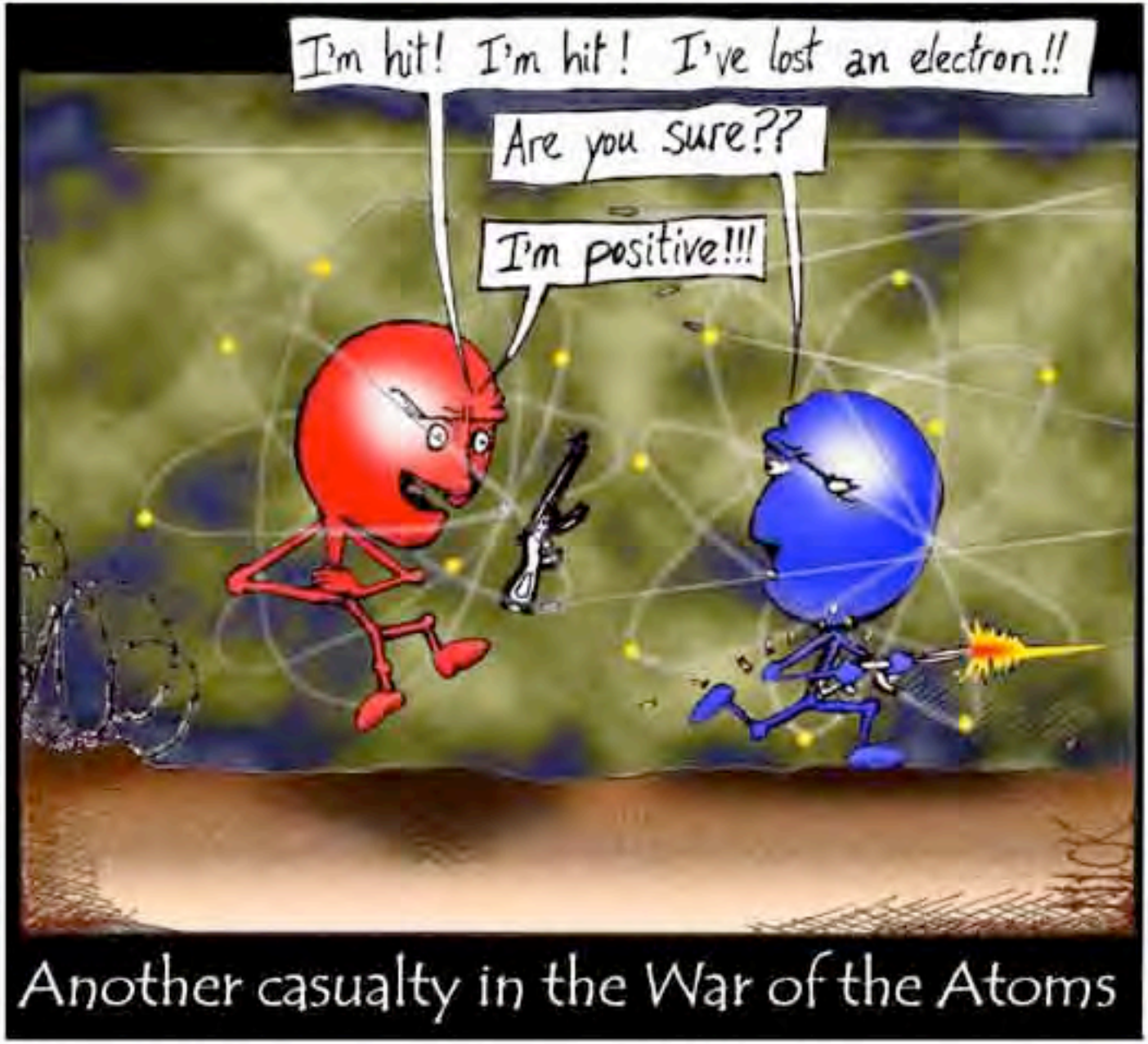
- Like Charges Repel, Opposite Charges Attract, With a Magnitude Calculated From Coulomb's Law: $F=kq_1q_2/r^2$

- Atoms Have a Positive Nucleus and a Negative "Cloud".

- Electron Clouds Can Combine and Flow Freely in Conductors; Are Stuck to the Nucleus in Insulators.

- We Can Charge Objects by Transferring Charge, or by Induction.

- Electrical Charge Is Conserved, and Quantized.



STRANGE MATTER
by nick d. kim strange-matter.com