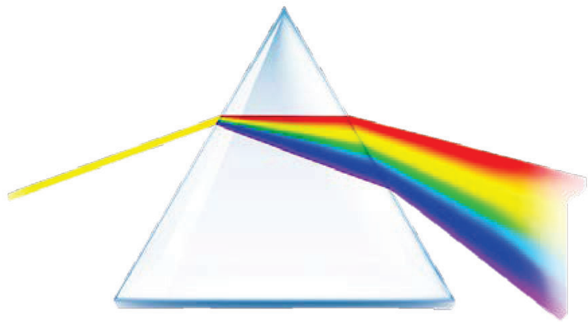
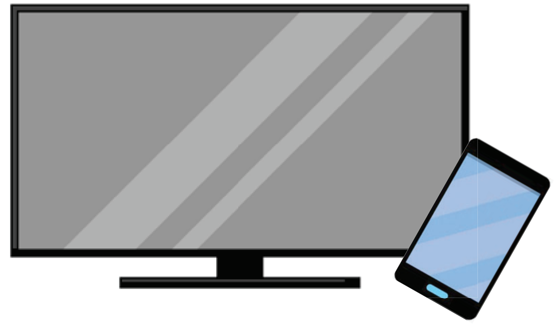
WHERE DO WE SEE ELECTRICITY AND MAGNETISM?

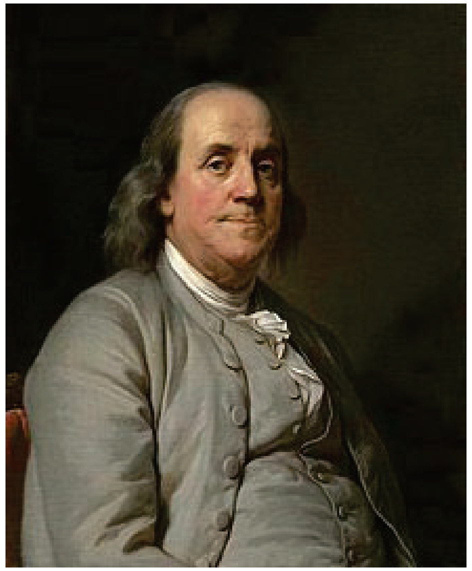




A BRIEF WALK THROUGH HISTORY

<u>600 BC</u>: Greeks called amber "electron" as it would attract straw when rubbed against cloth

<u>1752</u>: Benjamin Franklin had many breakthroughs



- Kite experiment (lightning ↔ electricity)
- Charges: opposites attract, likes repel
- "Electrical Fluid" through all matter

A BRIEF WALK THROUGH HISTORY

1784: Henry Cavendish defines the inductive capacity of dielectrics/insulators

1786: Charles de Coulomb

- Coulomb's Law: inverse square law of electrostatics

$$\overrightarrow{F_{\boldsymbol{Qq}}} = \frac{kQq}{r^2}\widehat{r_{Qq}}$$

- Unit of charge is Coulomb

THE ELECTRIC CHARGE

Atom: nucleus with surrounding electron cloud

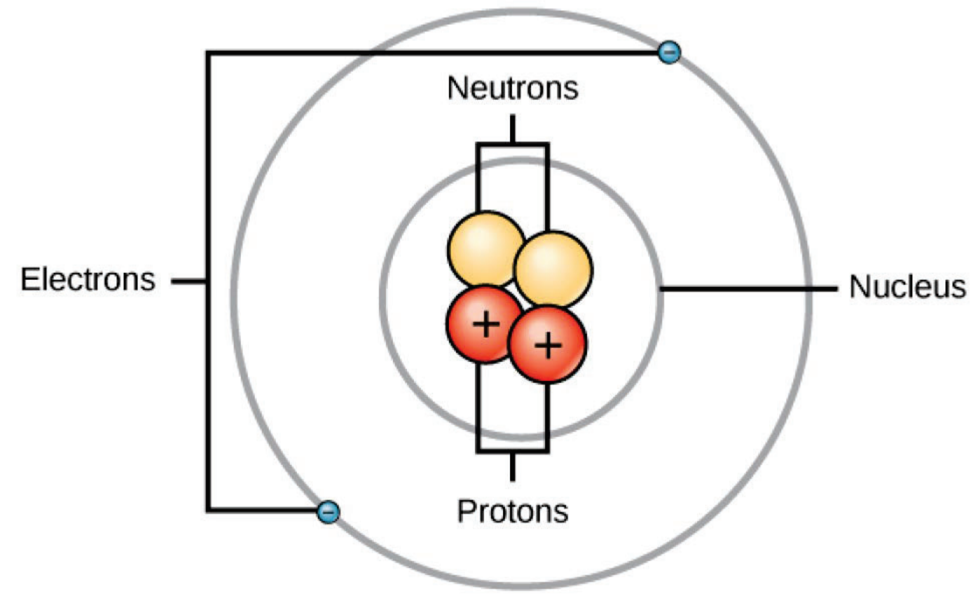
- Nucleus has protons and neutrons

Charge:

- Protons are +ve; Electrons are –ve
- Same magnitude of charge: 1.6 x 10^{-19} C

Mass:

- $m_p \approx m_n \approx$ 1.7 x 10^{-27} kg
- $m_e \approx$ 9.1 x 10^{-31} kg



THE TRIBOELECTRIC EFFECT

When we rub two objects with each other, small amounts of charges are transferred from one object to another

Triboelectric series gives us tendency of material to acquire a positive charge

Q1: If I rub amber with fur, what's going to happen?

Q2: What about rubbing glass rod with silk?

CONSERVATION OF ELECTRIC CHARGE

The electric charge is a **conserved quantity**

- We cannot create or destroy an electric charge
- But we can distribute them to create particles and localized areas with varying charges

Conservation of Electric Charge:

- The net electric charge in an isolated system must remain constant

We can never violate this principle!

QUANTIZATION OF CHARGE

Elementary/Fundamental Charge:

- The fundamental charge of the electron q_e is -1.602 x 10^{-19} C
- Charge involved in transfer of electrons must be integer (n) multiples of the fundamental charge; $Q = nq_e$

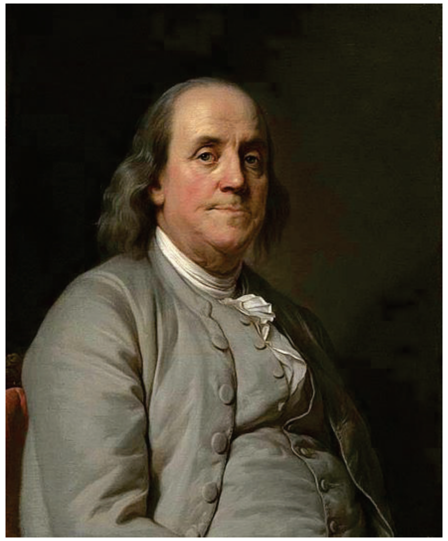
Classical vs. Quantum Worlds:

- Classical world deals with charges of μC, 13 orders larger than q_e; quantization can be neglected
- Only worry about this in quantum electronics

BENJAMIN FRANKLIN'S OBSERVATIONS

Benjamin Franklin demonstrated numerous concepts:

1. Like charges repel; opposite ones attract
2. The more charges present, the greater the force
3. The closer the charged object, the larger the magnitude of the force
4. Some materials "conduct" charges while others do not (conductors vs. insulators)

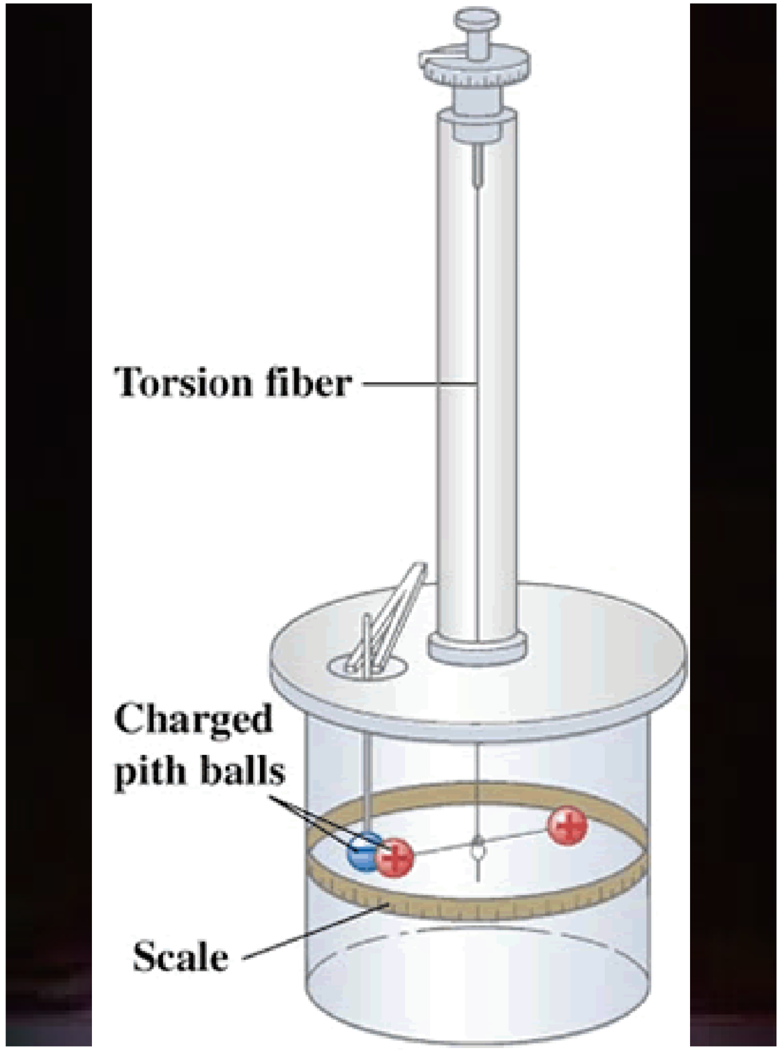


How can be describe these observations mathematically?

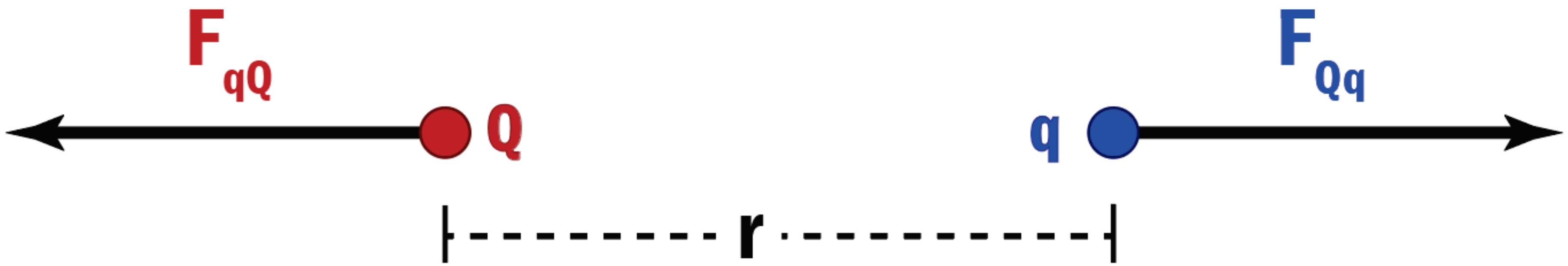
COULOMB'S TORSION BALANCE EXPERIMENT

Charles Augustin de Coulomb:

- In the late 1700s, he used a **torsion balance** to investigate electrostatic force



COULOMB'S LAW



$$\overrightarrow{F_{qQ}} = \frac{kQq}{r^2}\widehat{r_{qQ}} \quad \text{and} \quad \overrightarrow{F_{Qq}} = \frac{kQq}{r^2}\widehat{r_{Qq}} = -\overrightarrow{F_{qQ}}$$

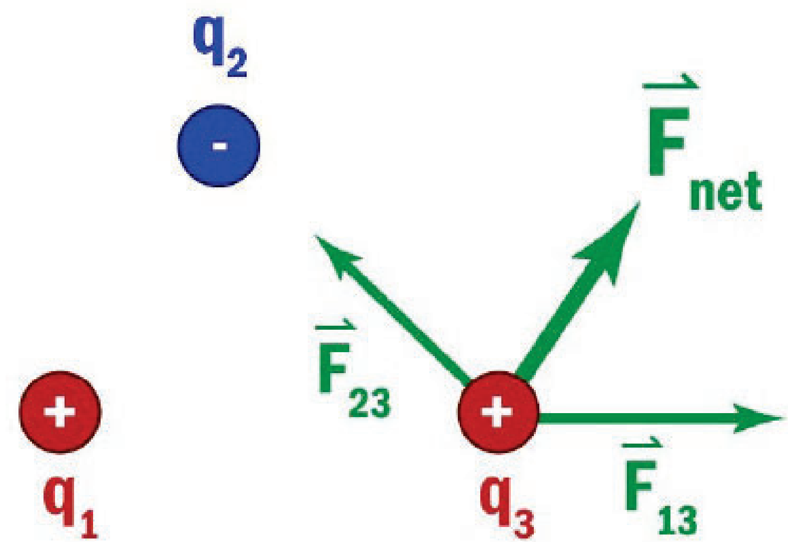
Units: Charges [C], Forces [F], Distance [m]

Coulomb's Constant: $k = \frac{1}{4\pi\epsilon_0} \approx 8.99 \times 10^9\ Nm^2/C^2$

Where $\epsilon_0 = 8.854 \times 10^{-12}\ m^{-3}kg^{-1}s^4A^2$ is called the **permittivity of free space**

PRINCIPLE OF SUPERPOSITION

If there are more than two charges, how can we calculate the electrostatic force?



We use the **principle of superposition**!

- It allows us to find the **net electrostatic force** on one point charge
- We add up individual vector forces on the charge

- All of E&M is based on this principle, as it has been verified by every experiment done on it

DOES COULOMB'S LAW ALWAYS WORK?

Are there conditions for when we can apply Coulomb's Law?

- Charged bodies must be very small compared to r
- Force must be inversely proportional to r^2

<u>Q & A</u>:

1. **How much is "very small" and how was Coulomb sure of the accuracy of the inverse-square law?**
   - Cavendish and Maxwell's experiments proved $<10^{-6}$ error
   - We now know this error is 10^{-16}
2. **Is there a distance r where Coulomb's Law doesn't work?**
   - Less than 10^{-16} m is when EM theory may not work at all
   - It's been proven up to 10^{8} m