I. Two kinds of charge

1. Plastic rubbed up for "negative"
2. Glass rubbed up silk "positive"

Like repel, opposite attract

Total charge of isolated system is conserved.

Equal quantity of "negative" and "positive" is neutral. We can then use an algebraic sign:

\[ q_{\text{net}} = q_1 + q_2 \]

II. Coulomb's law

Experimentally,

\[ F = \frac{k q_1 q_2}{r^2} \]

If measured in empirical unit Coulomb (C)

\[ k = 0.9 \times 10^{-10} \text{ Nm}^2 \text{C}^{-2} = \frac{1}{4\pi E_0} \]

We will come to \( E_0 \). What is \( 4\pi \)?
repulsive force of 2 $1e$ like charges placed 1 meter apart,$\text{ }$

$$F = k \frac{1e^2}{(1m)^2} = 10^{10} N$$

equivalent to weight of 1 billion kg @ surface Earth!

III. the Neutral Atom

fundamental unit of charge in the electron

$$e = 1.6 \times 10^{-19} C$$

Atom is neutral for very deep reasons:

$$z(e_p + e_e) = z(e - e) = 0 \text{ exactly}.$$ 

Compare

$$\frac{Ke^2}{Gm^2} \approx 10^{+36}$$
IV. Electric Conductivity

Different materials have very different electrostatic behavior due to mobility of electrons. Two large classes:

1) **Conductors**
   - Metals have highly mobile electrons ("free"), typically 1/atom allowing negative or positive ("holes") to move freely.

2) **Insulators**
   - No mobile electrons allow static charge to remain fixed on surface, difficult to remove. Glass, plastic, rubber, styrofoam.

![Diagram]

- **Charged, conducting sphere** - charge uniformly distributed on surface.
- **Switch**  
  "ground" - large source/sink of charge

Conductors will rapidly discharge to ground.
Induced charge:

- Insulating sphere
- Conducting sphere has induced charge separation.

V. Superposition of Forces

Example 1

\[ F_c + \vec{W} + \vec{T} = 0 \]

At equilibrium, \[ F_c + \vec{W} + \vec{T} = 0 \]

L to T, \[ F_c \cos \theta = \vec{W} \sin \theta \]
\[ F_c = \vec{W} \tan \theta = \vec{W} \theta \]
\[ x/2L = \sin \theta \approx \theta \]

\[ \frac{k \theta^2}{x^2} = mg \frac{x}{2L} \Rightarrow \theta = \sqrt{\frac{mgx^3}{2kL}} \]
\[ \theta = \left[ \frac{10^{-2} \text{kg} \cdot 10^{-7} \text{C}^2 \cdot (0.1 \text{ m})^3}{0.9 \times 10^{10} \text{ Nm}^2 / \text{C}^2 \cdot (2 \text{ m})} \right]^{1/2} \left[ \frac{1}{2(0.8)} \times 10^{-10} + 1.3 \right]^{1/2} 
\approx 56 \text{nc} \quad (\text{nm} = \text{C}) \]

**Example** uniform line of charge

**Charge/length** \( \lambda = \frac{Q}{2a} \)

- Plane of charge: \( y = 0 \)\( \quad \phi = 2 \pi \)

- \( \theta = \frac{x}{\sqrt{x^2 + y^2}} \)

- \( \phi = x \quad F = x^2 F_x \)

\[ F_x = 2k\phi \int_0^{\infty} \frac{dy}{(x^2 + y^2)^{3/2}} \]

\[ = \frac{2k\lambda}{x} \int_0^{\infty} \frac{du}{(1 + u^2)^{3/2}} = \frac{2k\lambda}{x} \frac{u}{\sqrt{1 + u^2}} \]

\[ \phi = \frac{2k\lambda x}{x} \lim_{u \to \infty} \frac{u}{\sqrt{1 + u^2}} \quad \phi \to \infty \]

\[ \approx \frac{2k\lambda}{x} \]