Lecture 2
Chapter 25
Electric charge and Coulomb's Law

→ Coulomb's experiments showed that electric force exerted by one charged body on another depends directly on the product of magnitudes of 2 charges and inversely on the square of their separation ⇒ $F \propto \frac{|q_1||q_2|}{r^2}$

Magnitude of mutual force that acts on each of the 2 charges q_1 and q_2

r^2 → distance between their centers.

→ Required by Newton's third law, force exerted by q_1 on q_2 is equal in magnitude but opposite in direction to the force exerted by q_2 on q_1 although the magnitudes of charges may be different.

Difference:

Gravitional forces

↓

Always attractive

Electrostatic forces

↓

Can be attractive or repulsive depending on whether the two charges have same/opp. sign.

S.I System: Const. $K = \frac{1}{4\pi\epsilon_0}$ — ③

ϵ_0 = electric constant (permittivity) = $8.854 \times 10^{-12}\ C^2/N.m^2$

$$K = \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9\ N.m^2/C^2$$

$$\left[\frac{1}{4 \times 3.14 \times 8.854 \times 10^{-12} C^2/N.m^2} = \frac{10^{12}}{111.15} = 8.9 \times 10^{12-3} = 8.9 \times 10^9\right]$$

Sample Problem 25-2. In Sample Problem 25-1 we saw that a copper penny contains both positive and negative charges, each of a magnitude 1.37×10^5 C. Suppose that these charges could be concentrated into two separate bundles, held 100 m apart. What attractive force would act on each bundle?

Solution From Eq. 25-4 we have

$$F = \frac{1}{4\pi\epsilon_0}\frac{|q|^2}{r^2} = \frac{(8.99 \times 10^9\ \mathrm{N\cdot m^2/C^2})(1.37 \times 10^5\ \mathrm{C})^2}{(100\ \mathrm{m})^2}$$

$$= 1.69 \times 10^{16}\ \mathrm{N}.$$

12,744 km

This is about 2×10^{12} tons of force! Even if the charges were separated by one Earth diameter, the attractive force would still be about 120 tons. In all of this, we have sidestepped the problem of forming each of the separated charges into a "bundle" whose dimensions are small compared to their separation. Such bundles, if they could ever be formed, would be blasted apart by mutual Coulomb repulsion forces.

The lesson of this sample problem is that you cannot disturb the electrical neutrality of ordinary matter very much. If you try to pull out any sizable fraction of the charge contained in a body, a large Coulomb force appears automatically, tending to pull it back.

$$= \frac{16.87 \times 10^{19}}{10^4}$$

$$= 16.87 \times 10^{15}\ \mathrm{N}$$

$$= 1.69 \times 10^{16}\ \mathrm{N}$$

1 tonn 9806.65 N

1 N = 1.01×10^{-4} tonn

SAMPLE PROBLEM 25-4. The nucleus of an iron atom has a radius of about 4×10^{-15} m and contains 26 protons. What repulsive electrostatic force acts between two protons in such a nucleus if they are separated by a distance of one radius?

Solution From Eq. 25-4 we have

$$F = \frac{1}{4\pi\epsilon_0}\frac{e^2}{r^2} = \frac{(8.99 \times 10^9\ \mathrm{N \cdot m^2/C^2})(1.60 \times 10^{-19}\ \mathrm{C})^2}{(4 \times 10^{-15}\ \mathrm{m})^2}$$

$$= 14\ \mathrm{N}.$$

The large repulsive electrostatic force, more than 3 lb and acting on a single proton, must be balanced by the attractive nuclear force that binds the nucleus together. This force, whose range is so short that its effects cannot be felt very far outside the nucleus, is known as the "strong nuclear force" and is very well named.

Roman word 'Libra'

1 lb (pound) = 0.45 kg

1N = 0.22 lbs