Introduction

Go over the roll and introductory handout.

Review of Physics 4A

Newton's Laws of Motion explain the concept of force.
1. Newton's First Law - The Law of Inertia
    describes the natural state of motion as constant velocity
    defines force as the thing that causes changes from this natural state
2. Newton's Second Law - $\sum F=ma$
    defines mass as the inertia of an object
    quantifies the amount of force required to make a given change in motion
3. Newton's Third Law - The Law of Action/Reaction
    forces always occur in action/reaction pairs

Conservation Laws
1. Conservation of Energy
2. Conservation of Linear Momentum
3. Conservation of Angular Momentum

Study of the Gravitational Force
1. The Law of Universal Gravitation $F_g = G\frac{m_1 m_2}{r^2}$

Preview of the Rest of Physics

The Four Fundamental Forces

Name of Force	Strength	Example
Gravitational	1	Solar System
Electromagnetic	10^{36}	Hydrogen Atom
Weak Nuclear	10^{25}	Beta Decay
Strong Nuclear	10^{38}	Nuclear Stability

The most common force in every day life is the electric force. All contact forces (friction, normal, tension, pushes pulls, etc.) are actually electrical in nature. These electric forces are the topic for the next 15 weeks.

Chapter 22 - Electric Charge

Problem Set #1 - due:
Ch 22 - 3, 5, 8, 10, 12, 20, 28, 29

The fundamental electric interaction is the force exerted and felt by electric charges.

Lecture Outline
1. The Properties of Electric Charge
2. The Electric Force and Coulomb's Rule

<u>1. The Properties of Electric Charge</u>

Pith Balls, plastic rod, fur

Notice:
1) This force is stronger than gravity.
2) Unlike gravity, there is attraction and repulsion.
3) Objects sometimes feel the force and sometimes don't.

This force is called the "electric force." Things that feel (and exert) this force are said to be "charged." Recall that things that feel (and exert) the gravitational force have mass and there is only attraction.

There must be two types of charge to account for both attraction and repulsion. They are called "positive" and "negative." From the pith ball demonstration it can be seen that like charges repel and opposite charges attract.

The Units of Charge: The "fundamental" unit of charge in the universe is the electron's charge, e.
The S.I. unit of charge is the "Coulomb."

1 Coulomb = 1C and $1e = 1.602 \times 10^{-19}C$

(Note that e is a positive number, but the charge of an electron is defined to be negative.)

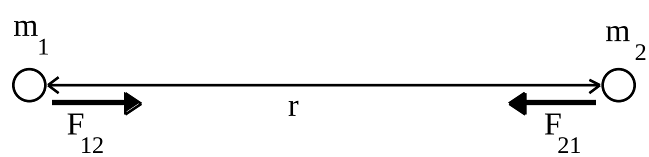
Charge comes in integral multiples of the charge on the electron. The charge on any object is a multiple of the charge on the electron (q=Ne). Charge is said to be “quantized.”

Summary of the Properties of Electric Charge:
1)Charge is always conserved (Law of Conservation of Charge).
2)There are two types called "positive" and "negative."
3)Charge is quantized (q=Ne).

Discuss these properties in terms of the atomic nature of matter.
Discuss these properties in terms of bulk properties of conductors and insulators.

2. The Electric Force and Coulomb's Rule

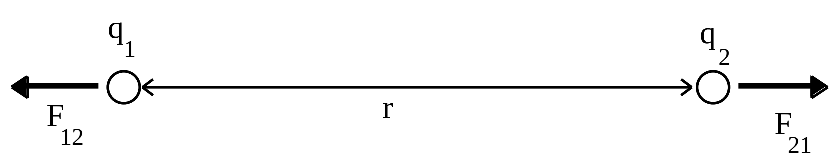
Gravitational Force:



Newton's Third Law requires that $F_{12} = F_{21}$. Therefor, m_1 and m_2 must show up in a symmetric way (eg. m_1m_2 or $m_1+ m_2$). This led us to the Law of Universal Gravitation,

$$\vec{F}_g = G\frac{m_1m_2}{r^2}\hat{r}$$

Electrical Force:



Again, Newton's Third Law requires that $F_{12} = F_{21}$. Therefor, q_1 qnd q_2 must show up in a symmetric way (eg. q_1q_2 or q_1+q_2). By analogy with the Law of Gravitation, $F_{12} \alpha\ q_1q_2$.

You might suspect that the force decreases with the distance, $F\alpha\frac{1}{r^n}$.

Experiments indicated that (like gravity) n is almost exactly equal to two.

In summary,

$$\boxed{\vec{F}_e = k\frac{q_1 q_2}{r^2}\hat{r} \qquad \text{Coulomb's Rule}}$$

where $\hat{r}$ points from the charge that causes the force toward the charge that feels the force and

$$k \equiv \frac{1}{4\pi\varepsilon_o} = 9.00\text{x}10^9\ \frac{\text{N m}^2}{\text{C}^2} \quad \text{where } \varepsilon_o = 8.85\text{x}10^{-12}\ \frac{\text{C}^2}{\text{N m}^2}$$

<u>Example 1:</u> Find the electric force that a proton exerts on an electron in a hydrogen atom. Compare the result with the gravitational force between the two.

$q_1 = -1.6\text{x}10^{-19}\text{C}$

$q_2 = +1.6\text{x}10^{-19}\text{C}$

$r = 0.052\text{nm}$

Using Coulomb's Rule,

$$\vec{F}_e = k\frac{q_1 q_2}{r^2}\hat{r}$$

$$F_e = (9.00\text{x}10^9)\frac{(1.6\text{x}10^{-19}\text{C})^2}{(0.052\text{x}10^{-9}\text{m})^2} = \underline{\underline{8.5\text{x}10^{-8}\text{N}}}$$

$m_1 = 9.1\text{x}10^{-31}\text{kg}$

$m_2 = 1.67\text{x}10^{-27}\text{kg}$

$G = 6.67\text{x}10^{-11}\ \frac{\text{N m}^2}{\text{kg}^2}$

Using the Law of Universal Gravitation,

$$\vec{F}_g = G\frac{m_1 m_2}{r^2}\hat{r}$$

$$F_g = (6.67\text{x}10^{-11})\frac{(9.1\text{x}10^{-31})(1.67\text{x}10^{-27})}{(0.052\text{x}10^{-9})^2} = \underline{\underline{3.7\text{x}10^{-47}\text{N}}}$$

The ratio is a staggering $\frac{F_e}{F_g} = 2.3\text{x}10^{39}$ which is why electric wires work when they run uphill!

<u>Example 2:</u> Estimate the number of excess electrons on a pith ball.

$\ell \approx 0.20\text{m} \quad \theta \approx 20^\circ,\ m \approx 0.010\text{kg}$

Applying Newton's Second Law,

$\sum F_x = F_e - F_t\sin\theta = 0$ and $\sum F_y = F_t\cos\theta - mg = 0$

$F_e = mg\tan\theta$

Using Coulomb's Rule, $\vec{F}_e = k\frac{q_1 q_2}{r^2}\hat{r}$

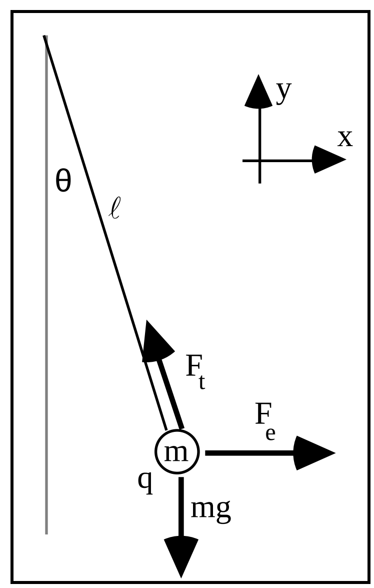
$$F_e = k\frac{q^2}{r^2} = k\frac{q^2}{(2\ell\sin\theta)^2}$$

Set the two expressions for F_e equal and solve for q,

$$q = \sqrt{\frac{4mg\ell^2\sin^2\theta\tan\theta}{k}} = \underline{\underline{2.7\text{x}10^{-7}\text{C}}}$$

This is some multiple of the charge on one electron,

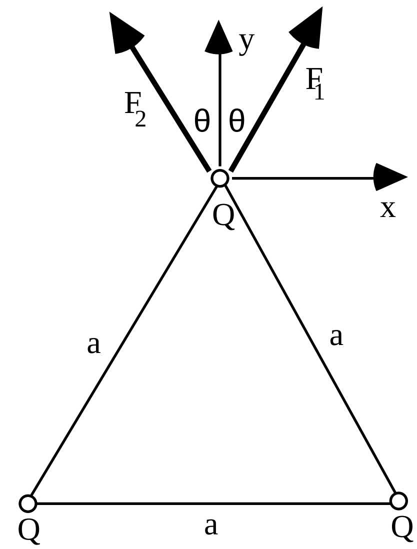
$$q = Ne \qquad N = \frac{q}{e} = \underline{\underline{1.7\text{x}10^{12}\text{electrons}}}$$



<u>*Example 3:*</u> *Equal charges Q are placed at the vertices of an equilateral triangle with sides of length a. Find the force on each charge.*

Note that $\theta = 30^\circ$. Using Coulomb's Rule, $\vec{F}_e = k\dfrac{q_1q_2}{r^2}\hat{r}$,

$$F_1 = F_2 = k\frac{Q^2}{a^2}$$



Adding up the components of the force vectors,

$$\sum F_x = F_1\sin\theta - F_2\sin\theta = 0$$
$$\sum F_y = F_1\cos\theta + F_2\cos\theta = 2F_1\cos\theta$$
$$= 2\,k\frac{Q^2}{a^2}\frac{\sqrt{3}}{2} = \sqrt{3}k\frac{Q^2}{a^2}$$

The direction is away from the center.

<u>**Chapter 22 - Summary**</u>

Summary of the Properties of Electric Charge:
1)Charge is always conserved(Law of Conservation of Charge).
2)There are two types called "positive" and "negative."
3)Charge is quantized (q=Ne).

Coulomb's Rule $\vec{F}_e = k\dfrac{q_1q_2}{r^2}\hat{r}$