Chapter 1 Electrostatic Field

1.1 Charge and Matter

1.2 Electric Field and Intensity

1.3 The Gauss's Law For **E**

1.4 The Circuital Law for E

1.1 Charge and Matter

Electromagnetism-a Preview

- 600 B.C.—— Ancient Greece, Thales
  - Amber (resin) attracts light objects
  - Iron rich rocks from Magnesia attract iron

- 1730 -C. F. du Fay: Two kinds of charges

  Positive and Negative

  - Positive: obtained rubbing glass with silk
  - Negative: obtained rubbing amber with fur

1.1 Charge and Matter

Electromagnetism-a Preview

- 1766-1786 – Priestley/Cavendish/Coulomb
  - EM interactions follow an inverse square law
  - Actual precision better than $2/10^9$!
- 1800 – Volta
  - Invention of the electric battery

N.B.: Till now Electricity and Magnetism are disconnected!

Nota bene

1.1 Charge and Matter

Electromagnetism-a Preview

- 1820- Oersted and Ampere
  - Established first connection between electricity and magnetism
- 1831— Faraday
  - Discovery of magnetic induction
- 1873—Maxwell: Maxwell's equations
  - The birth of modern Electro-Magnetism

1.1 Charge and Matter

Electromagnetism-a Preview

- 1887—Hertz
  - Established connection between EM and radiation
- 1905—Einstein
  - Special relativity makes connection between Electricity and Magnetism as natural as it can be!

1.1 Charge and Matter

The Electric Charge

- Two kinds of charge

  Positive and Negative (Benjamin Franklin)

  - Positive: obtained by rubbing glass with silk
  - Negative: obtained by rubbing resin with fur

- Two kinds of actions

  Repulsions and Attractions

  - Repulsions : Like charges repel.
  - Attractions : Unlike charges attract.

1.1 Charge and Matter

The Electric Charge

- Normal (Neutral) State
  - Matter : equal amounts of positive and negative electricity.
- Electrified Body: rubbing, induction,...
  - Upsetting the electric neutrality of matter

1.1 Charge and Matter

The Electric Charge

- Demonstration of electric forces

Charged by rubbing

1.1 Charge and Matter

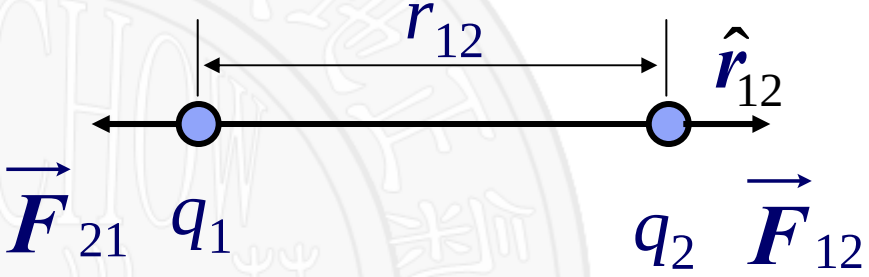
Coulomb's Law

Attraction between charges

From OCW of mit

Coulomb's Law

$$\vec{F}_{12} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}^{\ 2}}\hat{r}_{12}$$



- $F_{12}$is the force that the charge q_2 feels due to q_1
- $\hat{r}_{12}$ is the unit vector going from q_1 to q_2
- $1/4\pi\varepsilon_0 = 8.99 \times 10^9 NC^{-2}m^2$
- $\varepsilon_0 = 8.85 \times 10^{-12} N^{-1}C^2m^{-2}$,permmitivty for free space

1.1 Charge and Matter

Coulomb's Law

- Consequences
  - Newton's third law:

$$\vec{F}_{12} = -\vec{F}_{21}$$

  - Like signs repel, opposite signs attract.


Repulsion between charges


Attraction between charges

- Point Charge：
  - The distance apart is much bigger than their size.

1.1 Charge and Matter

Coulomb's Law

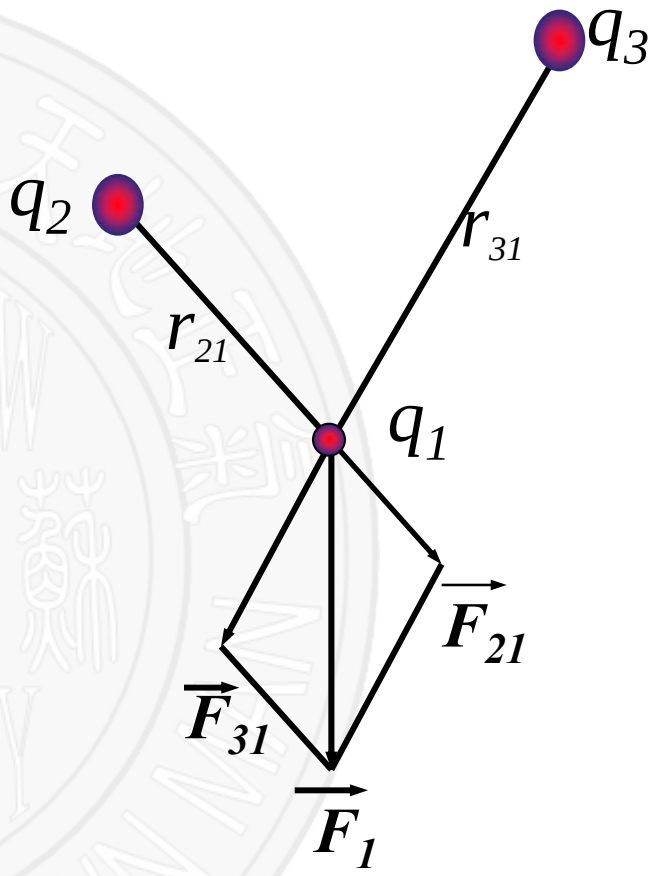
Superposition principle (SP)

A Group of Charges

$$\vec{F}_1 = \vec{F}_{21} + \vec{F}_{31} \cdots \vec{F}_{i1}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{q_2 q_1}{r_{12}^{\ 2}}\hat{r}_{21} + \frac{1}{4\pi\varepsilon_0}\frac{q_3 q_1}{r_{13}^{\ 2}}\hat{r}_{31}$$

$$\cdots + \frac{1}{4\pi\varepsilon_0}\frac{q_i q_1}{r_{1i}^{\ 2}}\hat{r}_{i1}$$



Vector sum: rectangular or triangle principle

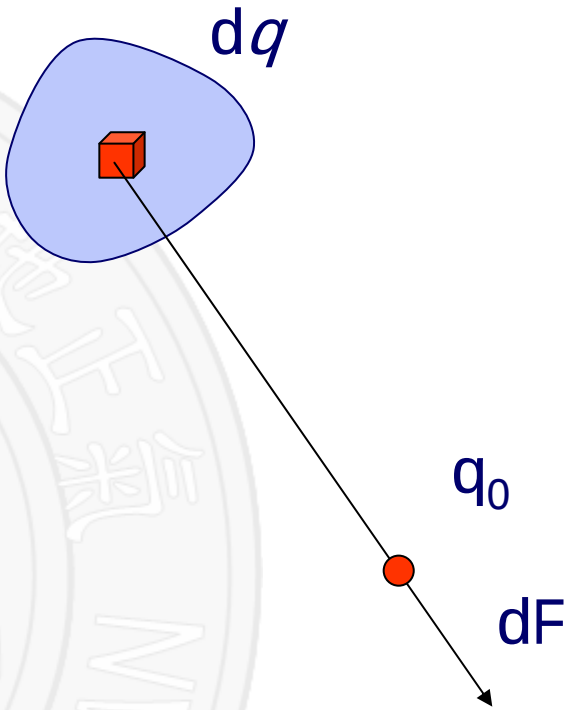
1.1 Charge and Matter

Coulomb's Law

Superposition principle (SP)

Continuous Distribution of Charges

$$\vec{F} = \int d\vec{F} = \int \frac{1}{4\pi\varepsilon_0}\frac{q_0 dq}{r^2}\hat{r}$$



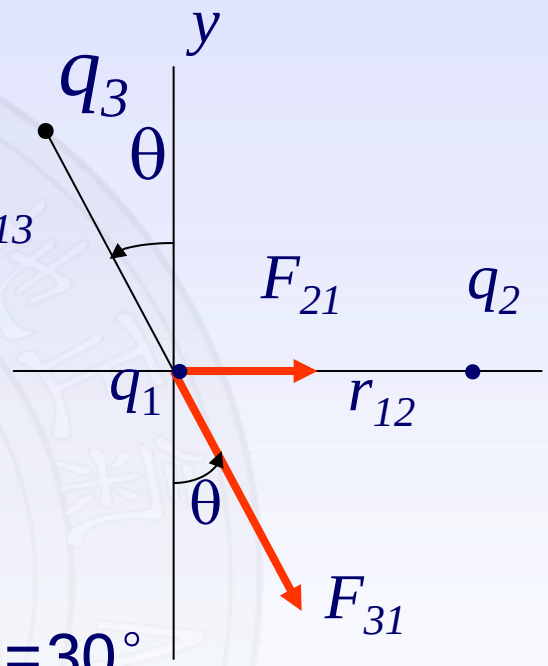
dq : Infinitesimal Charge

- $dq=\rho dV$, volume charge
- $dq=\sigma dS$, surface charge
- $dq=\lambda dl$, line charge

1.1 Charge and Matter

Coulomb's Law

- Superposition principle (SP)



Example 1.1

Three fixed charges q_1, q_2 and q_3

What force acts on q_1?

$q_1=-1.0\times10^{-6}$C, $q_2=+3.0\times10^{-6}$C,

$q_3=2.0\times10^{-6}$C. $r_{12}=15$cm, $r_{13}=10$ cm, $\theta=30^\circ$

Solution:

$$F_{21}=\frac{1}{4\pi\pi_0}\frac{q_1q_2}{r_{12}^2}=\frac{(9.0\times10^9)(1.0\times10^{-6})(3.0\times10^{-6})}{(1.5\times10^{-1})^2}$$

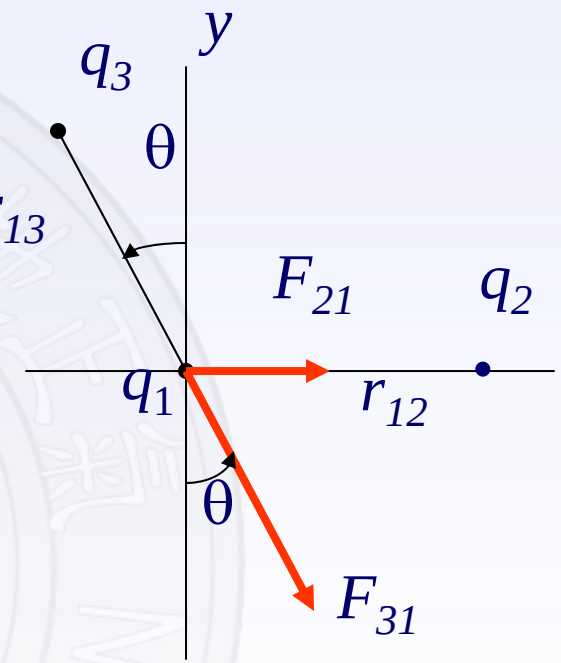
$$=1.2(N)$$

1.1 Charge and Matter

Coulomb's Law

- Superposition principle (SP)

Example 1.1



$$F_{21} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}^2}$$

$$= \frac{(9.0\times10^{9})(1.0\times10^{-6})(3.0\times10^{-6})}{(1.5\times10^{-1})^2} = 1.2(N)$$

$$F_{31} = \frac{(9.0\times10^{9}\times1.0\times10^{-6}\times2.0\times10^{-6})}{(1.0\times10^{-1})^2} = 1.8(N)$$

1.1 Charge and Matter

Coulomb's Law

- Superposition principle (SP)

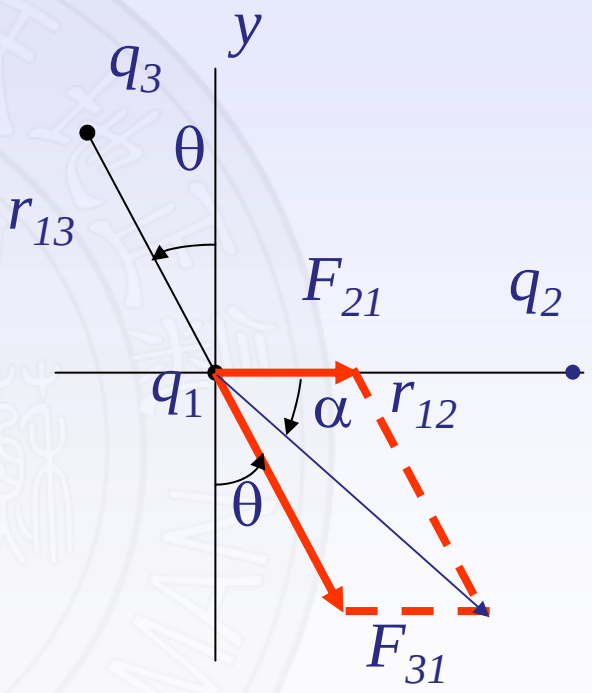
Example 1.1

$$F_{1x}=F_{21x}+F_{31x}=F_{21}+F_{31x}\sin\theta$$

$$=1.2N+(1.8N)\sin 30^\circ=2.1N$$

$$F_{1y}=F_{21y}+F_{31y}=0-F_{31}\cos\theta$$

$$=-(1.8)(\cos 30^\circ)=-1.6N$$



$$F_1=\sqrt{F_{1x}^2+F_{1y}^2}=2.64(N)$$

$$\alpha=\arctan\frac{F_{1y}}{F_{1x}}=-52^\circ 41'$$

1.1 Charge and Matter

- Electric charge is quantized (Millikan)
  - Electric charge (Franklin) continuous fluid
    - $dq=\rho dV$, volume charge
    - $dq=\sigma dS$, surface charge
    - $dq=\lambda dl$, line charge
  - Atomic theory: not continuous but quantized
    - Minimum charge $e=1.6027733\times10^{-19}$C.
    - Millikan's oil-drop experiment

1.1 Charge and Matter

Charge and Matter

- Atom
  - proton, +e, $m_p = 1.6726485 \times 10^{-27}$kg
  - neutron,0, $m_n = 1.6749543 \times 10^{-27}$kg
  - electron,-e, $m_e = 9.109534 \times 10^{-31}$kg
- Electric force and Gravity

  Gravity is much much ... smaller than Electric force!

1.1 Charge and Matter

Charge and Matter

Electric force and Gravity

Example 1.2 The distance r between the electron and the proton： 5.3×10^{-11}m. (a) the electrical force ? (b) the gravity

Solution:

According to the Coulomb's law, the electric force is

$$F_{Coulomb} = \frac{1}{4\pi\pi_0}\frac{q_1 q_2}{r_{12}^2}$$

$$= \frac{(9.0\times10^9\ N\cdot m^2/C^2)(1.6\times10^{-19}\ C)}{(5.3\times10^{-11}\ m)^2}$$

$$= 8.1\times10^{-8}\ N$$

1.1 Charge and Matter

- Electric force and Gravity

According to the Gravity's law, the gravity is

$$F_{Gravity} = G\frac{m_1 m_2}{r^2}$$

$$= 6.67\times10^{-11}\times\frac{9.11\times10^{-31}\times1.67\times10^{-27}}{\left(0.529\times10^{-10}\right)^2}N$$

$$= 3.63\times10^{-47}\,N$$

The ratio of $F_{Coulomb}$ and $F_{Gravity}$: 10^{39} orders!

1.1 Charge and Matter

Charge is Conserved

- The algebraic sum of the charges in the universe is constant.
- a fundamental law of physics

Thank you!

1.1 Charge and Matter

If you have any question or problem

Come and talk to me

You are welcome any time!

My mobile phone: 13646225169

emaile: lichengjin @ suda. edu. cn

QQ No: 564184500

Course web site:

http://jpkc.suda.edu.cn/ec2006/C75/

1.1 Charge and Matter

C.F.du Fay (14 September1698 – 16 July 1739) was a French chemist and superintendent of the Jardin du Roi.

He discovered the existence of two types of electricity and named them "vitreous" and "resinous" (later known as positive and negative charge respectively.) He noted the difference between conductors and insulators, calling them 'electrics' and 'non-electrics' for their ability to produce contact electrification. He also discovered that alike-charged objects would repel each other and that unlike-charged objects attract.He also disproved certain misconceptions regarding electric charge, such as that of Dr. Stephen Gray who believed that electric properties of a body depended on its colour.