PHYS212 - Chap 21 Notes - Coulomb's Law

Sam Nelson

5/6/2020

1 Introduction

Electrostatic force exerted by charged particles

Charles-Augustin de Coulomb - 1785

The mathmatical form of the law (vector):

$$\vec{F} = k\frac{q_1 q_2}{r^2}\hat{r} \tag{1}$$

Where:

q_1	Charge 1
q_2	Charge 2
r	Particle separation
$\hat{r}$	Unit vector
k	Electrostatic/Coulomb Constant

Note the similarity between Coulomb's law and Newton's equation for the gravitational force between two particles

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

The unit of charge is known as a *Coulomb* and is defined in relation to the *Ampere*

$$i = \frac{dq}{dt} \tag{3}$$

In this case, current is defined as the rate at which charge moves past a point or region.

Re-arranging, the units are related as so:

$$1C = 1A \times 1s \tag{4}$$

The magnitude of the electrostatic force is represented by:

$$F = \frac{1}{4\pi\epsilon_0} \frac{|q_1||q_2|}{r^2} \tag{5}$$

where $k = \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \, \mathrm{N} \cdot \mathrm{m}^2/\mathrm{C}^2$
or

$$k = \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \, \frac{\mathrm{N} \cdot \mathrm{m}^2}{\mathrm{C}^2} \tag{6}$$

with ϵ_0 known as the *Permittivity constant*

$$\epsilon_0 = 8.85 \times 10^{-12} \, \frac{\mathrm{C}^2 \cdot \mathrm{m}^2}{\mathrm{N}} \tag{7}$$

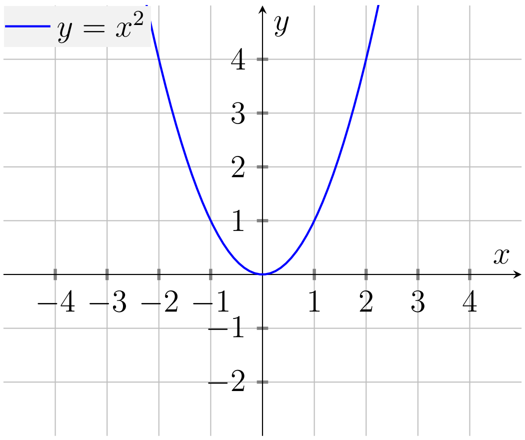
Principle of superposition. To find the net force on a particle, sum all the forces acting on that particle.

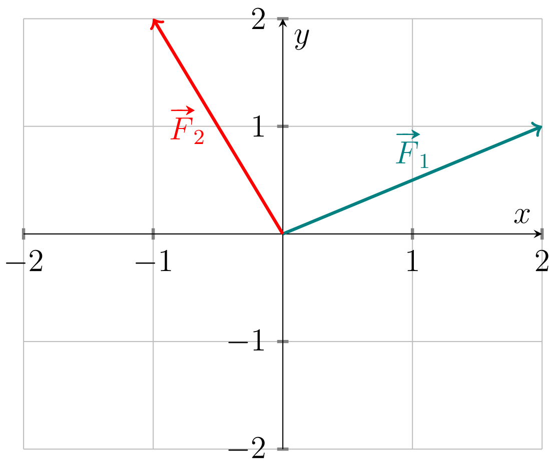
$$\vec{F_{1,net}} = \vec{F_{12}} + \vec{F_{13}} + \vec{F_{14}} + \vec{F_{15}} + \cdots + \vec{F_{1n,}} \tag{8}$$

$$\vec{F}_{1,\mathrm{net}} = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14} + \vec{F}_{15} + \cdots + \vec{F}_{1n,} \tag{9}$$

Shell theory 1 A charged particle outside a shell with charge uniformly distributed on its surface is attracted to or repelled as if the shell's charge were concentrated as a particle at its center.

Shell theory 2 A charged particle inside a shell with charge uniformly disributed on its surface has no net force acting on it due to the shell.





2 Quantization of Charge

Any positive or negative charge q that can be detected, can be written as

$$q = ne, \quad n = \pm 1, \pm 2, \pm 3, \ldots, \tag{10}$$

In which e, the **elementary charge,** has the approximate value

$$e = 1.602 \times 10^{-19}\,\mathrm{C} \tag{11}$$

3 Conservation of Charge

Charge is not created or destroyed, it is transfered. This hypothesis is known as **conservation of charge**.

An example is the radioactive decay of uranium-238 (^{238}U).

$$^{238}\mathrm{U} \longrightarrow {}^{234}\mathrm{Th} + {}^{4}\mathrm{He}, \tag{12}$$

The *parent* nucleus ^{238}U contains 92 protons, with a charge of $+92e$, the *daughter* nucleus ^{234}Th contains 90 protons, with a charge of $+90e$ and the emitted alpha particle ^{4}He contains 2 protons, with a charge of $+2e$. Total charge is $+92e$ before and after the decay, thus charge is conserved.

Another example of this charge conservation is when an electron e^- (charge $-e$) and its antiparticle, the *positron* e^+ (charge $+e$), undergo an *annihilation process*, transforming into two *gamma rays*:

$$e^- + e^+ \longrightarrow \gamma + \gamma \quad \text{(annihilation)}. \tag{13}$$