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The Forces Due to the Interactions Between the Particles

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Abstract **– In this work, the author presents the different forces generated by the interactions between the particles. Indeed, in the universe, matter differs. It is made up of charged particles and other neutrals. There are three interactions between the different forms of elementary particles: neutrons, protons and neutrons; or between atoms or even between larger particles, on a macroscopic scale. Those interaction are : atomic interactions on a nuclear scale, mass interactions in gravitational form and finally, electromagnetic reactions between particles and charged load.**

Keywords **– Particle, Nuclear Force, Gravitational Force, Electromagnetic Force, Electrostatic, Electrokinetic, Magnetostatic, Magnetic Induction.**

I. Introduction

In the article [5], the author spoke about matter and energy. In this article, we are interested in matter on a microscopic scale. Indeed, the matter that constitutes the universe is made up of elementary particles. These particles are either positively charged like the protons, or negatively like the electron or neutral like the neutrons. The three examples mentioned above form the atoms. The interactions between these particles have been studied by the scientists [6] and classified as follows:

1. Nuclear interactions: between protons and neutrons for the study of nuclei.
2. Gravitational interaction: between the masses. It is described by Newton's law, is studied in the science of mechanics.
3. Electromagnetic interaction: between particles and charged load.

These interactions are due to forces applied by the particles to each other. The modeling of the interactions of fixed particles is simpler than that of moving particles. Indeed, in the latter case, the movement of the particles varies over time. Thus, the spatio-temporal characteristics intervene in the study of the forces generated by these displacements.

II. Nuclear Interactions

The remote electrostatic influence of a conductor by a charged system modifies the distribution of its electrical charges but not its overall value.

Law of conservation of electrical charge: For an electrically isolated system, the total charge is constant.

Example 1

(1) If we illuminate an entity and negative charges are created in this system, then positive charges in equal quantities also appear. The emission of electrons by a material under the action of light is called the photoelectric effect.

(2) The law of conservation of charge is valid even in relativity. Indeed, the first postulate of relativity states that the laws of physics are the same in all inertial frames of reference. The second postulate of special relativity states that the speed of light c is a constant, independent of the relative motion of the source.

(3) All charged particles have mass, and massive particles can't move at exactly the speed of light c.

(4) All massless particles always travel at the speed of light, represented by the letter c, whereas massive particles can travel at any speed between zero and c. Since photons are massless, they travel at c. They are elementary particles with no charge and no resting mass.

In 1913, Robert Millikan's oil drop experiments, explained in the article [10], show that the electric charge varied discontinuously and is present in nature per unit in the form of:

$$q = m.e \qquad (1)$$

with

q: The charge of the particle.

m: A positive or negative integer.

e: The charge of an electron $e = 1.60219 \times 10^{-19} C$.

The elementary particles, stable constituents of matter, have as charges:

1) Elecron: $q = -e = -1.60 \times 10^{-19} C$

2) Proton: $q = +e = 1.60 \times 10^{-19} C$

3) Neutron: the charge is zero $q = 0$

The unit of the charge is the Coulomb in the S.I (MKSA). This is the amount of charge transported by a current of 1 Ampere for 1 second (Q = I.t) hence $1C = 6.25 \times 10^{18} e$. This is a high number of particles. In practice, we use the mC and μC. The sciences that study these interatomic particles depend on their movement as indicated in Table (1).

Table 1. The forces according to the mobility of the charged particles. For more details see [6].

Fixed Charges	**Mobile Charges**			
	In Constant Global Movement: Continuous Velocity		**In Motion Depending on the Time: Variable Velocity**	
Study of electrostatic forces (Coulomb's Law)	Study of permanent currents	Study of magnetic fields in relation to its surroundings (Lorentz Force)	Study of transient and sinusoidal regimes	Study of the connections between the electric and magnetic field
Electrostatic ($\vec{v} = 0, \vec{E}, V$)	Electrokinetics ($\vec{v} = constant, I$)	Magnetostatics ($\vec{v} = constant, \vec{B}, \vec{A}$)	Electrokinetics ($\vec{v} = \vec{v}(t), I = I(t)$)	Electromagnetic induction ($\vec{v} = \vec{v}(t),\ I = I(t), \vec{E}, \vec{B}$)
The variables are: $\vec{v}$ the speed of the particles, $\vec{E}$ electric fields, V the electric potential, I intensity of the electric current. A permanent current I is the source of a permanent magnetic induction field $\vec{B}$ and of the vector potential $\vec{A}$ from which it derives.				

III. Gravitational Interaction Force

Gravitational forces have a formulation of the same type as that of the electrostatic force. two loaded points of mass m_1 and m_2, whose respective centers are separated by the distance r_{12}, interact mutually with equal and opposite forces.

$$\overrightarrow{F_{12}} = -G\frac{m_1 m_2}{r_{12}^2}\overrightarrow{u_{12}} = -\overrightarrow{F_{21}} \quad (2)$$

with

$$G = 6.67\times10^{-11}\,MKSA(N\,m2/kg2) \quad (3)$$

These forces are of the form,

$$G\frac{u_r}{r^2} \quad (4)$$

and are called Coulomb forces. But they are still attractive.

At the atomic and subatomic scales, this force is negligible. The comparison, for example, of the gravitational force $\overrightarrow{F_g}$ and the electrostatic force $\overrightarrow{F_e}$ both exerted between the electron and the proton of a hydrogen atom shows a ratio of $\|\overrightarrow{F_e}\|/\|\overrightarrow{F_g}\|$ equivalent to 10^{39} times. On the other hand, it plays a fundamental role in the mechanics of macroscopic objects and in celestial dynamics.

IV. Electromagnetic Interaction Force

The study of these interactions are the subject of several sciences. According to the movement of the particles, immobile or mobile, we speak of electrostatics, magnetostatics or even electromagnetic induction.

4.1. *Electrostatic Interaction Force: Coulomb's Law or Fundamental Principle of Electrostatics*

The electrostatic forces are translated by the same type of formulation as the gravitational one. In 1784, the French physicist Charles-Augustin de Coulomb measured, using his torsion balance, the interaction forces between electric charges. His measurement results led to the following principle : In a vacuum, two stationary point electric charges q_1 and q_2, located at P_1 and P_2, exert an electrostatic force on each other. This force is directed according to the line (P_1P_2) which joins them and is repulsive if q_1 and q_2 are of the same sign and attractive otherwise. Its value is proportional to q_1, q_2 and inversely proportional to the square of the distance r_{12} which separates P_1 and $P2$. We denote by $\overrightarrow{u_{12}}$ the unit vector of the direction (P_1P_2) directed from P_1 to P_2 :

$$\overrightarrow{u_{12}} = \frac{\overrightarrow{P_1P_2}}{\|\overrightarrow{P_1P_2}\|} \quad (5)$$

the force $\overrightarrow{F_{12}}$ exerted by q_1 on q_2 and translated by Coulomb's law is written:

$$\overrightarrow{F_{12}} = \frac{Kq_1q_2}{r_{12}^2}\overrightarrow{u_{12}} \quad (6)$$

The coefficient K is a dimensioned proportionality constant, the value of which therefore depends on the unit chosen for the load. In the S.I , K is equivalent to $9\times10^9\ MKSA\ (Nm^2/C^2)$. By rationalization, we write: With these notations, Coulomb's law is written:

$$K = \frac{1}{4\pi\varepsilon_0} \quad (7)$$

$\approx 9\times10^9$MKSA

where ε_0 is the permitivity of the void and has the value in the S.I.

$$\varepsilon_0 = 8.8537 \times 10^{-12}\, F.m^{-1} \tag{8}$$

According to the principle of action and reaction, conversely, the charge q_2 exerts on q_1 a force equal and opposite to $\overrightarrow{F_{12}}$:

$$\overrightarrow{F_{21}} = -\overrightarrow{F_{12}} \tag{9}$$

4.2. *Electromagnetic Interaction Force: Lorentz Force*

The fundamental basis of electrostatics is Coulomb's law. It describes the interaction of two immobile charged particles. Magnetic interactions are manifested between moving charged particles. It would be tempting, by analogy, to state the force law between a particle carrying the charge q_1, located at M_1 and animated by the velocity $\overrightarrow{v_1}$ and a particle carrying the charge q_2, located at M_2 and animated by the velocity $\overrightarrow{v_2}$. In fact, it is a complex problem and difficult to solve with these data, to calculate the forces exerted on q_2 at the instant *t*, it is actually necessary to know the entire movement of q_1 prior to *t*. The classical approach consists in introducing the electric and magnetic fields:

Let be a point charge q located in M and animated by a speed $\vec{v}$ at the instant *t*. The electromagnetic force $\vec{F}$ experienced by this particle, called the Lorentz force, is given by:

$$\vec{F}(M) = q(\vec{E}(M) + \vec{v}(M) \wedge \vec{B}(M)) \tag{10}$$

The charge q is that which has been defined in electrostatics and it is independent of the velocity $\vec{v}$ of the particle. If $\vec{v} = 0$, the force $\vec{F}$ in the equation (10), reduces to the electric term, independent of the speed $\vec{v}$:

$$\overrightarrow{F_e}(M) = q\vec{E}(M) \tag{11}$$

If all the charges are stationary, the electric field merges with the electrostatic field. Otherwise, the electric field cannot be calculated by the formula for defining an electrostatic field.

4.3. *Electromotive Force of Induction: Faraday's Law-Lenz's Law*

In 1831, the physicist and chemist Michael Faraday discovers that an induced current is produced in a closed circuit located in a region where there is a magnetic field $\vec{B}$. This current is at the origin of the variation, as a function of time, of the flux $\vec{B}$ through the surface delimited by the circuit. The causes of this variation are mainly three.

In fact, the establishment of this induced electromotive force $\vec{e}$, results from the work of the magnetic force $\overrightarrow{F_m}$ or from the non-conservative circulation of an electric field, called induced field $\overrightarrow{E_\iota}$, which is linked to the magnetic force by

$$\overrightarrow{E_\iota} = \overrightarrow{F_m}/q = \vec{v} \wedge \vec{B} \tag{12}$$

(electromotive induction fields). Faraday's fundamental law is,

$$e = -d\varphi/dt \tag{13}$$

In this expression φ designates the flux at the instant *t* of the magnetic field $\vec{B}$ through the surface (S) delimit-

-ed by the circuit (*C*), seat of the induction phenomenon.

V. The Interactions between the Particles of a Cosmic Plasma

In space, there is a fourth state of matter that is not found anywhere on earth. An astrophysical plasma is an ionized gas which exists only in space. A large part of baryonic matter consists of plasma, a state of matter where molecules do not exist. Indeed, the atoms are so hot that they become ionized by splitting into ions (of positive charge) and electrons (of negative charge). Since the number of charges carried by the electrons and that of those carried by the ions in the plasmas are equal, the latter are generally electrically neutral and therefore the electric fields play a lesser dynamic role. Because plasmas are very conductive, any charge imbalance is quickly neutralized.

VI. Conclusion

In this article, the author presents the different types of interactions between particles. These interactions are the reflection of forces exerted by the particles between them. These forces are classified into three categories: nuclear forces, gravitational forces and electromagnetic forces. If the particles are charged, their studies are part of electromagnetic physics. Indeed, if they are fixed then the force studied is electrostatic. Otherwise, according to their movement, continuous or variable, we speak of magneto statics, electro kinetics or electromagnetic induction.

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A. Yosra Annabi, has a background in applied mathematics. She works on EDP, direct and inverse mathematical problems, mathematical modeling in medicine, hydrogeology and emotion.