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A Proposed Extension of Coulomb's Law of Electrostatic Force for a Moving Charged Particle

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1 Introduction

Coulomb's law of electrostatics gives the force **F** between two electric charges *Q* and *K* as:

$$\mathbf{F} = \pm \frac{QK}{4\pi\varepsilon_o Z^2}\hat{\mathbf{u}} = K\mathbf{E} \tag{1}$$

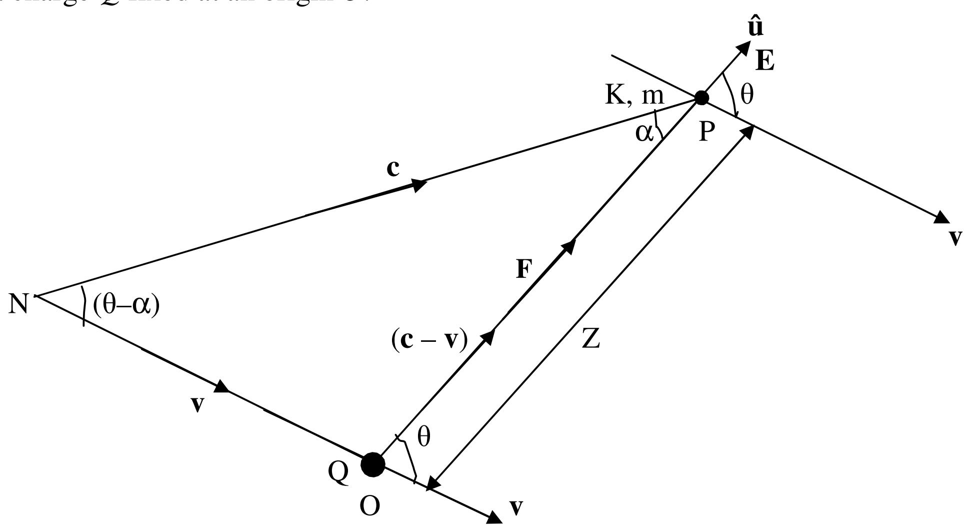
where ε_o is the permittivity of a vacuum, *Z* is the separation between the charges, ***E*** is the electric field intensity due to *Q* at the point of location of *K* and $\hat{\boldsymbol{u}}$ is a unit vector in the direction of the field. The force is repulsive (positive) for like charges and attractive (negative) for unlike charges and is supposed to be independent of the velocity of the charges.

Coulomb's law is, perhaps, the most significant principle in physics. Making this law independent of velocity of a moving charged particle, in an electric field, is identified as a mistake in physics, which led it into the wilderness of special relativity.

In this paper it is proposed that Coulomb force is dependent on the speed of a charged particle moving in an electric field. An extension of Coulomb's law is given in consideration of aberration of an electric field.

2 Aberration of Electric Field

The Figure below depicts a particle of charge *K* and constant mass *m* moving at a point *P* with velocity ***v*** at an angle *θ* to the accelerating force ***F*** due to an electric field of intensity ***E*** of a charge *Q* fixed at an origin *O*.



A particle of charge *K* and mass *m* moving at *P* with velocity ***v*** at an angle *θ* to accelerating force ***F***.

As a result of motion of the charged particle, the electric field appears to come along the line ***NP***, defined by velocity vector ***c***, displaced by a small angle α from the instantaneous line ***OP*** joining the charges *Q* and *K*, such that:

$$\sin\alpha = \frac{v}{c}\sin\theta \qquad (2)$$

where *c* is the speed of light in a vacuum. The small angle α, the angle of aberration, is due to aberration of electric field, a phenomenon similar to aberration of light discovered in 1728 by the English astronomer James Bradley. Equation (2) was first derived by James Bradley, from which he determined the speed of revolution of the Earth round the Sun.

3 Extension of Coulomb's Law for Electrostatic Force

Consider a particle of charge *K* moving with velocity ***v*** and acceleration *dv/dt* at time *t*, in an electrostatic field ***E*** due to another charge *Q*, The force of repulsion, equal to the accelerating force ***F***, is proposed, in accordance with Newton's second law of motion, as:

$$\mathbf{F} = \frac{QK}{4\pi\varepsilon_o cZ^2}(\mathbf{c} - \mathbf{v}) = m\frac{d\mathbf{v}}{dt} \qquad (3)$$

The vector ***(c − v)*** is the relative velocity of transmission of the accelerating force with respect to the moving charge *K*.

Equation (3) is the proposed extension of Coulomb's law. It takes into consideration the velocity of an electric charge *K* moving in the electric field due to a source charge *Q*. If the velocity ***v*** = ***c*** the accelerating force reduces to zero and the particle moves with constant velocity, in accordance with Newton's first law of motion.

Equation (3) may be expressed in terms of the modulus of a vector giving the accelerating force ***F*** as:

$$\mathbf{F} = \frac{QK}{4\pi\varepsilon_o cZ^2}\sqrt{c^2 + v^2 - 2cv\cos\left((\theta - \alpha)\right)}\,\hat{\mathbf{u}} = m\frac{d\mathbf{v}}{dt} \qquad (4)$$

where (θ − α) is the angle between the velocities (vectors) ***c*** and ***v***,

4 Accelerated Rectilinear Motion

The charged particle can move in a straight line with acceleration, where θ equal to zero, so that equation (2) and (4) give:

$$F = \frac{QK}{4\pi\varepsilon_o Z^2}\left(1 - \frac{v}{c}\right) = EK\left(1 - \frac{v}{c}\right) = m\frac{dv}{dt} \qquad (5)$$

The particle is accelerated to the speed of light *c* as maximum.

5 Decelerated Rectilinear Motion

In motion with θ equal to π radians, equation (2) and (4) give:

$$F = \frac{QK}{4\pi\varepsilon_o Z^2}\left(1 + \frac{v}{c}\right) = EK\left(1 + \frac{v}{c}\right) = -m\frac{dv}{dt} \qquad (6)$$

In this case the particle is decelerated to a stop and then accelerated in the opposite direction to reach the ultimate speed $-c$

5 Circular Motion

If K were a negative charge, such as an electron of charge $-e$ and mass m, it could revolve, with $\theta = \pi/2$ radians, in a circle of radius r with speed v and acceleration $-v^2/r$. Equation (2) and (4) give:

$$F = \frac{Qe}{4\pi\varepsilon_o Z^2}\sqrt{1-\frac{v^2}{c^2}} = \mathbf{e}E\sqrt{1-\frac{v^2}{c^2}} = m\frac{v^2}{r} \qquad (7)$$

The radius of revolution r increase with speed v, becoming infinitely large (motion in a straight line) if $v = c$.

6 Conclusion

Equations (5), (6) and (7) give the speed of light c as the ultimate limit with mass of a moving particle remaining constant but accelerating force depending on velocity. Not recognising the dependence of accelerating force on a charged particle on the velocity of the particle in an electric field is a serious mistake in physics. There is need to correct this mistake by extending Coulomb's law to take into consideration the dependence of accelerating force on a charged particle on velocity of the particle in an electric field. This will do away with the contraption of relativistic increase of mass with speed to explain the existence of a limiting speed equal to that of light in a vacuum.

