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An Alternative Explanation of the Result of Rogers' Experiment

Musa D. Abdullahi, U.M.Y. University
P.M.B. 2218, Katsina, Katsina State, Nigeria
E-mail: musadab@outlook.com, Tel: +2348034080399

Abstract

The result of Rogers' experiment with electrons made to revolve in circular orbits at definite speeds, can be explained as due to accelerating force, exerted by an electric field on an electron, perpendicular to the direction of motion, decreasing with speed and reducing to zero at the speed of light *c*. Consider an electron of charge *–e* and mass *m* revolving in a circle of radius *r* with speed *v* in a radial electric field of magnitude *E*. In classical electrodynamics, the electrostatic force or impressed force, *–eE*, is equal to the centripetal force, $-mv^2/r$, which makes $r = mv^2/eE$. As observed in cyclic accelerators, the radius *r* tending to become infinitely large at the speed of light (*v* = *c*) means that either *m* increases with speed to become infinitely large at the speed of light, in accordance with relativistic electrodynamics or *E* decreases with speed to become zero at the speed of light, in accordance with an alternative electrodynamics. The alternative explanations leads to the speed light *c* being the ultimate limit with mass of a moving particle remaining constant.

Keywords: Acceleration, mass, rectilinear and circular motion, special relativity, speed.

1. Introduction

In classical electrodynamics [1, 2], the mass of a particle is independent of its speed and an electric force can accelerate a charged particle beyond the speed of light. But observations on accelerated electrons, the lightest particles known in nature, showed that their speeds could not exceed that of light. Relativistic electrodynamics [3, 4] and an alternative electrodynamics [5] deal with the factors that restrain accelerated charged particles from going beyond the speed of light.

Relativistic electrodynamics explains the speed of light being a limit by positing that the mass *m* of a moving particle increases with its speed *v*, becoming infinitely large at the speed of light *c*. The mass-velocity formula, of special relativity, is:

$$m = \frac{m_o}{\sqrt{1-\frac{v^2}{c^2}}} = \gamma m_o \qquad (1)$$

where m_o is the rest mass and γ the Lorentz factor. This formula is supposed to be applicable in rectilinear motion as well as in circular motion round a central force of attraction.

In equation (1), the difficulty with infinite masses, which should be the mass of the whole universe, at the speed of light, is avoided by insisting that the speed *v* may be as near as possible, but it never really becomes equal to *c*. Photons, as "particles" supposed to move at the speed of light, are given zero rest mass.

This paper proposes that the speed of light *c* is an ultimate limit because the accelerating force exerted by an electric field, on a moving charged particle, decreases with the speed of the particle. The electric field and resulting accelerating force and acceleration reduce to zero at the speed of light and the particle continues to move at that speed with the rest mass m_o.

Decrease of accelerating force with speed, in the circular revolution of an electron round a central force of attraction, gives the same effect as apparent increase in mass with speed in accordance with equation (1). Therefore, Roger's experiment (1939) [6], supposed to have proved increase of mass with speed, might as well have confirmed decrease of accelerating force with speed, as far as circular motion round a central force of attraction is concerned.

In this paper the motion of electrons, in an electric field, is treated under classical, relativistic and an alternative electrodynamics. It is found that the result of Rogers' experiments is in agreement with predictions of the alternative electrodynamics, but not on the basis of mass increasing with speed to become infinitely large at the speed of light. In the alternative electrodynamics, it is shown that the speed of light is a limit not because mass becomes infinitely large at that speed but as a consequence of accelerating force exerted by an electric field, on a moving electron, decreasing with speed, reducing to zero at the speed of light.

2. Classical electrodynamics

Figure 1 shows an electron of mass *m* and charge *–e* revolving in a circle of radius *r* in a radial electric field of intensity **E** due to a point charge *Q* at the centre *O*. The accelerating force **F**, in accordance with Newton' second law of motion, is given by vector equation:

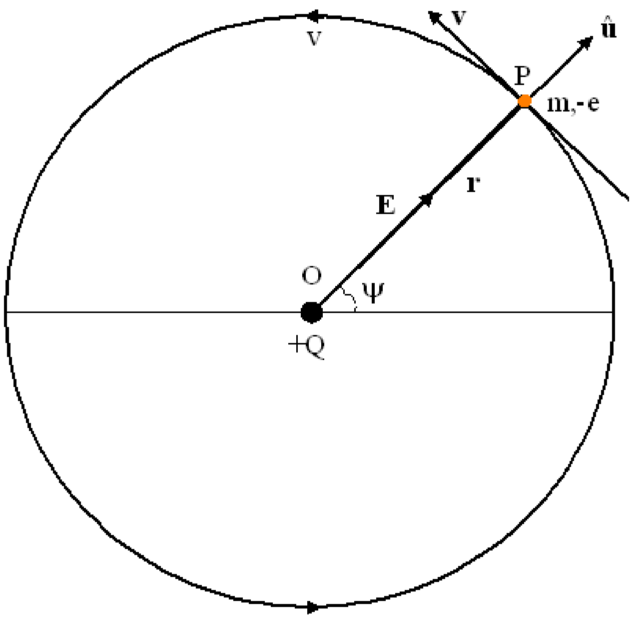

Figure 1. An electron of mass *m* and charge *–e* revolving with speed *v* in a circle of radius *r*, in a radial electric field of intensity ***E*** due to a positive charge *Q* at the centre *O*.

$$\mathbf{F} = -e\mathbf{E} = m\frac{d\mathbf{v}}{dt} = -m\frac{v^2}{r}\hat{\mathbf{u}} \tag{8}$$

where $(-v^2/r)\hat{\mathbf{u}}$ is the centripetal acceleration.. The scalar equation is:

$$eE = m\frac{v^2}{r} \tag{9}$$

$$\frac{eEr}{m_o v^2} = \frac{m}{m_o} = 1 \tag{10}$$

where m_o is the rest mass. In classical electrodynamics, mass *m* equal to the rest mass m_o is a constant and equation (10) should give a unity for all values of *E*, *r* and *v*. This is not what was observed in laboratory experiments.

3. Relativistic electrodynamics

In relativistic electrodynamics, the accelerating force **F** on an electron is independent of its velocity ***v*** at time *t* in an electric field of intensity **E**, but the mass *m* increases with speed *v* in accordance with the mass-velocity formula (1). In Figure 1, constant centripetal acceleration gives equation (8) as the accelerating force. Combining equation (9) with equation (1), gives:

$$eE = m\frac{v^2}{r} = \frac{m_o}{\sqrt{1-\frac{v^2}{c^2}}}\frac{v^2}{r} \tag{11}$$

$$\frac{eEr}{m_o v^2} = \frac{m}{m_o} = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \quad (12)$$

M. M. Rogers' experiment set out to verify equation (12) and it did so convincingly, in contrast to equation (10). The experiment provided an evidence of apparent increase in mass of a particle with its speed in accordance with the theory of special relativity.

4. Alternative electrodynamics

Figure 2 depicts an electron of charge $-e$ and constant mass $m = m_o$, moving at a point P with velocity **v** at time t, in an electric field of intensity **E** due to a stationary source charge $+Q$ at the origin O. The velocity **v** is at an angle θ to the accelerating force **F**, which is a force of attraction in the **PO** direction. The relative velocity between the accelerating force (propagated with velocity of light **c**) and the electron moving with velocity **v**, is vector (**c** – **v**). The velocity of light **c**, is inclined at aberration angle α to **F**, such that:

$$\sin\alpha = \frac{v}{c}\sin\theta \quad (13)$$

where v and c are the magnitudes of the velocities **v** and **c** respectively.

In the alternative electrodynamics, the accelerating force **F**, with reference to Fig..2, is vector:

$$\mathbf{F} = \frac{eE}{c}\left(\mathbf{c}-\mathbf{v}\right) = m\frac{d\mathbf{v}}{dt} \quad (14)$$

where E is the magnitude of the electric field of intensity **E**.

Expanding equation (14) by taking the *modulus* of the vector (**c** – **v**), with respect to the angles θ and α in Figure 2, gives the equation:

$$\mathbf{F} = \frac{-eE}{c}\sqrt{c^2 + v^2 - 2cv\left\{\cos\left(\theta-\alpha\right)\right\}}\,\hat{\mathbf{u}} = m\frac{d\mathbf{v}}{dt} \quad (15)$$

where $(\theta - \alpha)$ is the angle between the vectors **c** and **v** and **û** is a unit vector in the direction of the field **E,** opposite to the direction of (**c** – **v**). The electron can move in a straight line, in the direction of the force, with acceleration where $\theta = 0$ or against the force with deceleration where $\theta = \pi$ radians or it can revolve in a circle, with constant speed v, if θ is equal to $\pi/2$ radians.

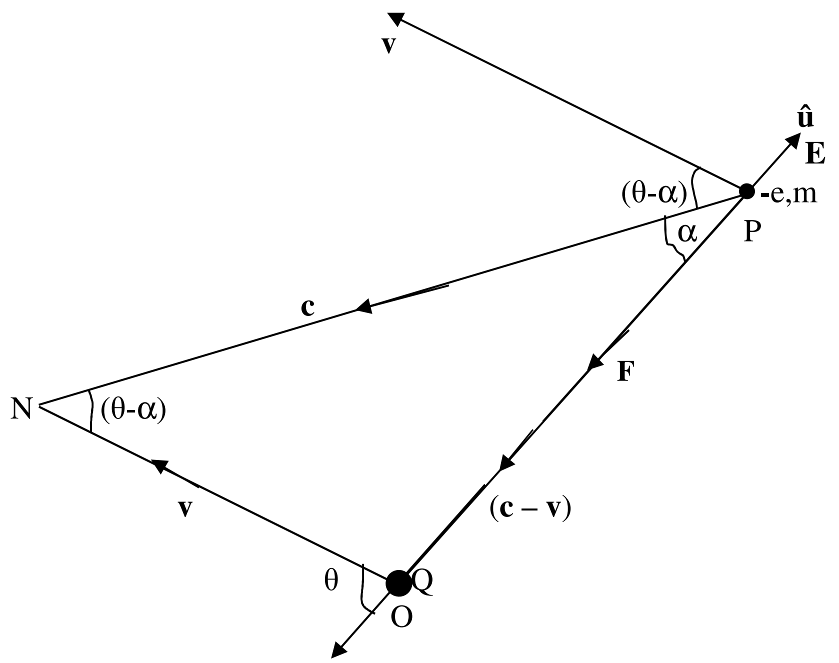

Figure 2. An electron of charge $-e$ and mass m moving, at P, with velocity **v**, at an angle θ to the accelerating force **F**. The unit vector **û** is in the direction of the electrostatic field **E** due to a positive charge Q fixed at O.

4.1 Circular Revolution

With the angle $\theta = \pi/2$ radians, the electron revolves in a circle of radius r with constant speed v and centripetal acceleration $(-v^2/r)\hat{\mathbf{u}}$. Noting that $cos(\pi/2 - \alpha) = sin\alpha$, equations (13) and (15) give:

$$\mathbf{F} = -eE\sqrt{1-\frac{v^2}{c^2}}\hat{\mathbf{u}} = -m\frac{v^2}{r}\hat{\mathbf{u}} \tag{16}$$

It is as if, in circular revolution, the radial electric field E_v varies with peripheral speed v as:

$$E_v = E\sqrt{1-\frac{v^2}{c^2}} \tag{17}$$

where $E = E_o$ is the electric field on a stationary charge.

Equation (16) with with mass m equal to the rest mass m_o, gives:

$$eE = \frac{m}{\sqrt{1-\frac{v^2}{c^2}}}\frac{v^2}{r} = \frac{m_o}{\sqrt{1-\frac{v^2}{c^2}}}\frac{v^2}{r}$$

$$\frac{eEr}{mv^2} = \frac{eEr}{m_o v^2} = \frac{E}{E_v} = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \tag{18}$$

Equation (18), which is on the basis of electric field decreasing with speed, is identical to equation (12), which is on the basis of mass increasing with speed. So Roger's experiment might have confirmed equation (18) rather than equation (12)

4.2 Radius of revolution in a circle

In classical electrodynamics, the radius of circular revolution of an electron of charge $-e$ and mass $m = m_o$ in a radial electrostatic field of magnitude E due to a central source charge, as given by equation (9), is:

$$r_o = \frac{m_o v^2}{eE} \tag{19}$$

where r_o is the classical radius.

In relativistic electrodynamics, the radius of circular revolution, as in equation (12), is:

$$r = \frac{mv^2}{eE} = \frac{m_o v^2}{eE\sqrt{1-\frac{v^2}{c^2}}} = \gamma r_o \tag{20}$$

The alternative electrodynamics (equation 20) gives the radius of circular revolution as:

$$r = \frac{mv^2}{eE\sqrt{1-\frac{v^2}{c^2}}} = \frac{m_o v^2}{eE\sqrt{1-\frac{v^2}{c^2}}} = \gamma r_o \tag{21}$$

Thus, relativistic electrodynamics (equation 20) gives the same expression for the radius of circular revolution of an electron, as the alternative electrodynamics (equation 21). As the speed of light is approached, the radius of revolution tends to infinity to make for motion in a straight line.

5. Roger's experiment

An experiment by M. M. Rogers [6] seems to support the relativistic mass-velocity formula. In this experiment, an electron of mass m, moving at a well-defined speed v, was made to enter a radial electric field. The electron was deflected to move in a circle of radius r under a centripetal accelerating force of magnitude F, to give equation (12) for m/m_o. The results of Roger's experiment are shown in Table 1.

TABLE 1. RESULTS OF ROGER'S EXPERIMENT FOR THREE DIFFERENT SPEEDS
($c = 2.998 \times 10^8$ m/sec, $e/m_o = 1.759 \times 10^{11}$ C/kg)

SPEED v m/sec	v/c	$Er \times 10^5$ V	OBSERVED m/m_o	CALCULATED $\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$
1.900×10^8	0.634	2.671	1.302	1.293
2.087×10^8	0.696	3.487	1.408	1.393
2.247×10^8	0.750	4.341	1.512	1.511
2.998×10^8	1.000	?	?	∞

The observed values of the ratio m/m_o, obtained for three different speeds, by measuring *Er*, and the calculated values from equation (12), were in close agreement, as shown in Table 1. Roger's experiment has seemingly verified the relativistic increase of mass of an electron with its speed *v*, becoming infinitely large at the speed of light. However, the speed is never allowed to reach that of light *c*, in spite of Bertozzi's experiment which showed that electrons are easily accelerated to the speed of light through a potential energy of 15 MeV or over.

6. Conclusion

Rogers' experimental results (Table 1) are in agreement with relativistic electrodynamics (equation 12) and the alternative electrodynamics (equation 18) for an electron of charge $-e$ and mass *m* revolving with speed *v* in a circle of radius *r*, under the influence of a radial electrostatic field of magnitude *E*. It could, therefore, be concluded that the predicted increase of mass of a particle with its speed, might have been confirmed.

The relativistic mass *"m"* in equation (1), is not a physical mass, but the ratio of the force *(eE)* on a stationary electron to the centripetal acceleration (v^2/r) in circular motion. This ratio (eEr/v^2) may become infinite for motion in a circle of infinite radius (a straight line), without any difficulty. Thus, we have the speed of light as the limit without infinite mass. Identifying equation (1) as increase in mass with speed is an expensive case of mistaken identity. It is also a good example of Beckmann's *correspondence theory* [8] whereby the mathematics is correct but the physical interpretation is wrong.

Relativistic electrodynamics and the alternative electrodynamics merge to classical at very low speeds. Relativistic electrodynamics and the alternative electrodynamics give zero acceleration at the speed of light. In relativistic electrodynamics, an electron cannot attain the speed of light *c*, no matter the magnitude of accelerating potential. In the alternative electrodynamics an electron is easily accelerated to the speed of light by a potential energy of 15 Mev or over.

Relativistic electrodynamics (equation 20) gives the same expression, for radius of circular revolution of an electron, as the alternative electrodynamics (equation 21). The radius can increase and become infinite for motion in a straight line, but the physical mass (equation 1), cannot expand and become infinitely large while its physical becomes infinitesimal.

Decrease of accelerating force with speed, as predicted by the alternative electrodynamics, gives the same effect as apparent increase of mass with speed, as far as circular revolution of an electron is concerned. What actually increases with speed is the radius of revolution in circular motion as expressed in equation 21. This radius can become infinite with speed, for rectilinear motion. So, if the alternative electrodynamics is valid, the relativistic mass-velocity formula is applicable only to circular revolution of an electron round a centre of force of attraction. Applying this formula to rectilinear motion of electrons in a linear accelerator, was wrong.

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