The Physical Meaning of Fine-Structure Constant

Huan Liang[1]

[1]Affiliation not available

July 23, 2023

Abstract

This paper aims to provide the physical meaning of fine-structure constant through simple mathematical derivations to prove that the value represents a ratio of the distance traveled by a single electron in a specific amount of time to the distance traveled by a single photon in the same amount of time.

The Physical Meaning of Fine-Structure Constant

Author: Huan Liang
Email: yybake@139.com
Affiliation: Independent researcher

Abstract

This paper aims to provide the physical meaning of fine-structure constant through simple mathematical derivations to prove that the value represents a ratio of the distance traveled by a single electron in a specific amount of time to the distance traveled by a single photon in the same amount of time.

Keywords

Fine structure constant, work, speed of light

1. Introduction

The fine structure constant is calculated as $\alpha = \frac{e^2}{4\pi\varepsilon 0 hc}$. If we want to know the true physical meaning of the value, then we shall understand what the physical meaning behind this equation is, because this is where this value comes from.

2. Mathematical Derivation

As it can be seen from the equation, this is a ratio of a speed of something to the speed of light, so it can be written as:

$$\alpha = \frac{e^2}{4\pi\varepsilon 0\hbar c} \quad \rightarrow \quad \alpha = \frac{e^2}{4\pi\varepsilon 0\hbar}/c$$

Then, the numerator of the above equation must be a velocity value, that is, a value of distance/time. After handling the numerator in the above equation as follow, obtain:

$$\frac{e^2}{4\pi\varepsilon 0} \quad \rightarrow \quad \frac{e^2 r^2}{4\pi\varepsilon 0 r^2} \quad \rightarrow \quad \frac{e^2}{4\pi\varepsilon 0 r^2} r^2 \quad \rightarrow \quad f_e r^2$$

Meanwhile, the reduced Planck constant can be written as:

$$\hbar = fst$$

Where r is the distance travelled by the electron causing by electrostatic force, and s is the distance travelled by the electron causing by the energy of one ħ. When r=s, then f_e=f, obtain:

$$\alpha = \frac{e^2}{4\pi\varepsilon 0\hbar}/c \quad \rightarrow \quad \alpha = \frac{f_e r^2}{fst}/c \quad \rightarrow \quad \alpha = \frac{r}{t}/c$$

Finally, in the same amount of time t, obtain:

$$\alpha = \frac{r}{t}/c \quad \rightarrow \quad \alpha = \frac{r}{t}/\frac{d}{t} = \frac{r}{d}$$

Where r is the distance traveled by the electron, d is the distance traveled by the photon, and the fine structure constant is the ratio of the two.

3. Conclusions

As for why the value is about 1/137, it is determined by the value of Planck constant. That is to say, the total energy represented by one Planck constant can only drive one electron that far, or can only give one electron such speed, as 1/137 of light speed. This is one postulate from Bohr's model of hydrogen atom.

CRediT authorship contribution statement

Huan Liang wrote the original draft and final version of above paper.

Declaration of Competing Interest

The author did not have any conflict of interest.

Declaration of Funding

There is no funding for this paper.

Data Availability Statement

All data, models, and code generated or used during the study appear in the submitted article.

References

[1]
https://baike.baidu.com/item/%E7%B2%BE%E7%BB%86%E7%BB%93%E6%9E%84%E5%B8%B8%E6%95%B0/4135506

[2]
https://baike.baidu.com/item/%E5%8A%9F/53648

[3]
https://baike.baidu.com/item/%E7%BA%A6%E5%8C%96%E6%99%AE%E6%9C%97%E5%85%8B%E5%B8%B8%E6%95%B0/18661583