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An Energy Formula That Is Physically Easier to Understand than $E = h\nu$

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Abstract

This paper rewrites the famous energy formula of quantum theory, $E = h\nu$, as a formula that is physically easier to understand. If we let m_e be the rest mass of the electron, c the speed of light in a vacuum, and λ_C the Compton wavelength of the electron, then the product of the three physical constants, $m_e c \lambda_C$, matches the value of the Planck constant. In the usual interpretation, h is regarded as a universal constant on a par with c. However, this paper holds that, contrary to the historical viewpoint, the Planck constant is logically nothing more than replacement of $m_e c \lambda_C$ with the alphabetic letter h. Thus, this paper looks for an energy formula that does not contain h. $E = h\nu$ is a formula that was assumed at the beginning, and then subsequently verified through experiment. The formula was not derived logically. In contrast, the energy formula derived in this paper can be derived logically. The formula derived in this paper also has a clear physical meaning, and it can be concluded that it is a superior formula to $E = h\nu$.

Keywords

Einstein-de Broglie's Relation, Planck Constant, Electron's Compton Wavelength, Classical Quantum Theory

1. Introduction

Below is Einstein's formula expressing the equality of energy and mass [1].

$$E = mc^2. \tag{1}$$

Meanwhile, Einstein's relational expression which applies Planck's quantum hypothesis to photons is as follows [2].

$$E = h\nu. \tag{2}$$

The photon's energy E is proportional to its frequency ν, and this constant of proportionality is known as the Planck constant. Formulas (1) and (2) are traditionally thought to be representative formula of the special theory of relativity and quantum mechanics, the roots of modern physics, and these two formulas have been thought to have similar importance.

However, Formula (2) includes the Planck constant h, which newly appeared in quantum theory. It is difficult to intuitively understand the meaning of Formula (2).

Thus, in this paper, the aim is to rewrite Formula (2) as a formula that is physically easier to understand.

Incidentally, in 1923, A. Compton introduced the definition of the Compton wavelength. According to Compton, the Compton wavelength is defined as the wavelength of a photon with the same amount of energy as the rest mass energy of a certain particle.

If ν_{C} is taken to be the frequency of light with a wavelength of λ_{C}, then the following relationship holds.

$$\lambda_{\mathrm{C}}\nu_{\mathrm{C}} = c. \tag{3}$$

Taking Formula (3) into account, Formula (1) can be written as follows.

$$m_{\mathrm{e}}c^2 = m_{\mathrm{e}}c \cdot \lambda_{\mathrm{C}}\nu_{\mathrm{C}} = m_{\mathrm{e}}c\lambda_{\mathrm{C}} \cdot \nu_{\mathrm{C}}. \tag{4}$$

The Planck constant can be defined as follows from Formula (4).

$$h = m_{\mathrm{e}}c\lambda_{\mathrm{C}}. \tag{5}$$

Due to Formula (5), an electron's Compton wavelength λ_{C} is represented by the following formula.

$$\lambda_{\mathrm{C}} = \frac{h}{m_{\mathrm{e}}c}. \tag{6}$$

Formula (6) is the exact definition of Compton wavelength introduced by Compton [3].

In the usual interpretation, h is thought to be a universal constant with the same value as the product of the three physical constants m_{e}, c, and λ_{C}.

However, the author has pointed out previously that the Planck constant is nothing more than the replacement of $m_{\mathrm{e}}c\lambda_{\mathrm{C}}$ with the alphabetic letter h [4]. That is,

$$m_{\mathrm{e}}c\lambda_{\mathrm{C}} \to h. \tag{7}$$

Of course, this differs from the historical view. It is likely that physicists did not notice the true meaning of h, and thus gave it the status of a universal constant.

What is obtained in experiments that determine the value of the Planck constant is not the value of h as a universal constant, but rather the value of h as the product of the three physical constants m_{e}, c, and λ_{C}. h has no profound meaning.

2. Formula for Energy That Is Easier to Understand than *E* = *hv*

This paper rewrites Formula (2) as a formula not containing h.

First, Formula (2) can be written as follows.

$$E = h \cdot \frac{c}{\lambda}. \quad (8)$$

Next, if the right side of Formula (5) is substituted for *h* in Formula (8), the following formula is obtained.

$$E = m_e c^2 \cdot \frac{\lambda_C}{\lambda}. \quad (9)$$

This is a formula for energy that does not include the Planck constant.

Here, let us define a ratio A as follows based on Formula (9).

$$\frac{E}{m_e c^2} = \frac{\lambda_C}{\lambda} = \mathrm{A}. \quad (10)$$

This paper does not rigorously discuss the value of A, but the value of A is likely to be in the following range.

$$0 < \mathrm{A} \le \frac{1}{2}. \quad (11)$$

Formula (10) shows that, when the wavelength λ of an emitted photon is 1/A times the Compton wavelength of the electron λ_C, the energy E of that photon becomes A times the rest mass energy of that photon $m_e c^2$.

However, this relationship can be simply predicted. Normally, finding Formula (9) from Formula (10) is regarded as the correct sequence.

Next, let us consider the relative merits of Formulas (8) and (9).

First, in Formula (8),

1) The light frequency c/λ is found from the wavelength of the observed light.

2) Next, the product of the obtained frequency and the Planck constant *h* is calculated.

With Formula (9) in contrast,

1) λ_0/λ is found from the wavelength of the observed light.

2) Next, the product of the ratio A of the two obtained wavelengths and $m_e c^2$ is calculated.

In the formula for energy, it is desirable for the ratio of the energy of the emitted photon and the rest mass energy of the electron to be clear. Formula (9) satisfies that requirement.

3. Derivation of Einstein—De Broglie's Relation Not Including *h*

Formula (2) was rewritten, so let us also rewrite the famous Einstein—de Broglie's relation as a formula that does not include *h*. Einstein—de Broglie's relation is indicated below.

$$\lambda = \frac{h}{p}. \quad (12)$$

Taking Formula (5) into account, Formula (12) can be written as follows.

$$\lambda = \lambda_{\mathrm{C}} \cdot \frac{m_{\mathrm{e}} c}{p}. \tag{13}$$

Here, if we compare Formulas (12) and (6), the momentum of a photon with wavelength λ_{C} becomes $m_{\mathrm{e}} c$.

$m_{\mathrm{e}} c$ is the momentum of a photon with energy equal to the rest mass energy of the electron.

Here too, let us define the following ratio B from Formula (13), as was done with Formula (10).

$$\frac{\lambda}{\lambda_{\mathrm{C}}} = \frac{m_{\mathrm{e}} c}{p} = \mathrm{B}. \tag{14}$$

Formula (14) shows that, when the momentum p of the photon or electron is 1/B times $m_{\mathrm{e}} c$, the wavelength of that quantum is B times the Compton wavelength of the electron.

4. Conclusions

The formula treated as a problem in this paper is the following formula that typifies quantum theory.

$$E = h\nu. \tag{15}$$

However, in comparing with the energy formula advocated by this paper, the following formula is preferable over Formula (15).

$$E = h\frac{c}{\lambda}. \tag{16}$$

In this paper, the following formula was derived as a formula for energy similar to Formula (16).

$$E = m_{\mathrm{e}} c^2 \cdot \frac{\lambda_{\mathrm{C}}}{\lambda}. \tag{17}$$

Formula (17) can be logically derived by two methods.

Formula (15), in contrast, cannot be derived logically. In this paper, we conclude that Formula (17) has a clearer physical meaning than Formula (15), and is a superior energy formula.

In this paper, Einstein—de Broglie's relation (12) was also rewritten as follows.

$$\lambda = \lambda_{\mathrm{C}} \cdot \frac{m_{\mathrm{e}} c}{p}. \tag{18}$$

We can say that convincing formulas are those where the energy formula includes the rest mass energy of the electron $m_{\mathrm{e}} c^2$, and where the formula for wavelength (18) includes the Compton wavelength λ_{C} of the electron.

In this paper, Formula (17) was derived by removing the Planck constant h from the formula for energy in quantum theory. Also, Formula (18) was derived by removing h from Einstein—de Broglie's relation. Formulas (17) and (18) are physically easier to understand than the existing formulas of quantum theory.

Finally, the formulas derived in this paper are summarized in the following **Table 1**.

Table 1. Distinctive features here are that the energy formula derived in this paper includes the rest mass energy of the electron $m_e c^2$, and the Einstein—de Broglie's relation includes the Compton wavelength of the electron λ_C.

	Quantum theory		This paper	
Energy formula in quantum theory	$E = h\nu$	(15)	$E = m_e c^2 \cdot \frac{\lambda_C}{\lambda}$	(17)
Einstein—de Broglie's relation	$\lambda = \frac{h}{p}$	(12)	$\lambda = \lambda_C \cdot \frac{m_e c}{p}$	(18)

Formula (17) is the truly correct formula for energy in quantum theory. The existing Formula (15) for energy was obtained by simplifying Formula (17) using Formula (7). Similarly, Formula (18) should be the correct formula for the relationship between wavelength and momentum. It was found that Formula (12) is a simplified version of Formula (18).

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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