The Heisenberg Principle of Temporary Violation of Energy Conservation

This work discusses the differences between the energy-time Heisenberg uncertainty relation and the temporary violation of energy conservation counterpart. Based on this counterpart, the meaning of the Planck energy, reduced Planck energy, Planck mass and reduced Planck mass are discussed.

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Contents

1. Introduction

In 1927 the German physicist Werner Heisenberg formulated a principle known as the Heisenberg uncertainty principle (or Heisenberg uncertainty relations). In this paper we shall discuss the energy-time relation only. This relation is given by

$$\Delta E \, \Delta t \geq \frac{\hbar}{2} \tag{1.1}$$

Where

ΔE = uncertainty in energy
Δt = uncertainty in time
$\hbar$ = reduced Planck's constant $(\hbar = h/2\pi)$

2. The Principle of Temporary Violation of Energy Conservation

The modern concept of empty space is that it is not empty at all. The so called quantum fluctuations of empty space produce pairs of virtual particles that live a relatively brief period of time. Paired virtual particles are virtual particles that can appear and disappear spontaneously in pairs. These particles are called virtual because (a) they can not be directly observed and because (b) they do not have a permanent existence. In fact, virtual particles could not be particles at all but something more subtle like deformations of space-time, excitations of quantum fields, etc. Despite this probable fact we shall still call them virtual particles. We know that virtual particles (or whatever) exist because there are a number of phenomena in which their brief presence can be "felt" and indirectly measured. For example, virtual particles cause changes (shifts) in the energy levels of atoms. The first physicist to measure changes in the energy levels of the hydrogen atom was Willis Lamb. Thus, the existence of virtual particles has been confirmed indirectly by experiments.

There are also virtual particles of a different type called force carrier particles. They transmit, for example, the electromagnetic force between two electrons, between two protons, or between and an electron and a proton. Therefore, we have two types of virtual particles:

(a) Paired virtual particles, and
(b) Force carrier particles (or force-carrying particles or, in short, force carriers).

Then, the inevitable question arises: which are the differences between these two types of virtual particles? There are, at least, two differences:

Difference 1.

Paired virtual particles, as the name indicates, always appear in pairs. One particle of the pair is made of normal matter (the one we call particle, for example a virtual electron), while the other is made of antimatter (which we call antiparticle, for example, a virtual positron). On the other hand, force carrier particles do not appear in pairs. When, for example, the electromagnetic force, say, between two electrons is exerted, a virtual particle, called *virtual photon*, is emitted by one of the electrons. Then, this virtual photon travels the distance separating the two electrons and finally is absorbed by the other electron. The result of this emission and absorption is what causes the force between the two real particles.

Difference 2.

While force carrier particles are responsible for transmitting the forces of nature, paired virtual particles do not transmit any force. The forces that transmit the force carrier particles are the electroweak force (electromagnetic force and the weak nuclear force) and the strong nuclear force. We still do not know if they are responsible for transmitting the gravitational force as well. Because the energy that gives rise to a force carrier particle seems to come from nowhere (or perhaps from the pre-universe), nature temporarily violates one of its most fundamental laws we study in classical physics: the law of conservation of energy.

Because in this article we are not dealing with uncertainties but with specific energies and with specific times, we need to consider another form of the Heisenberg uncertainty principle that instead of using uncertainties in energy and uncertainties in time, uses the energy and the lifetime of the virtual carriers involved. This form of the principle can be derived from the Heisenberg uncertainty relation (1.1) by introducing the following three changes:

(1) The uncertainty in energy, ΔE , must be replaced by the energy of the virtual particle (force carrier particle), E ,
(2) The uncertainty in time, Δt , must be replaced by the lifetime of the virtual particle (force carrier particle), τ , (the Greek letter tau), and
(3) The *greater than or equal to* sign must be replaced by the *less than or equal to* sign.

With these three changes, the energy-time Heisenberg uncertainty relation becomes the Heisenberg principle of temporary violation of energy conservation:

Principle of temporary violation of energy conservation
$$E \tau \leq \frac{\hbar}{2} \quad (2.1)$$

Where

$E =$ Total relativistic energy of the force carrier particle whose lifetime is τ
$\tau =$ Lifetime of the force carrier particle whose total relativistic energy is E

We can put this principle into words by saying that:

> The energy of a force carrier particle multiplied by its lifetime is less than or equal to the reduced Planck's constant divided by 2.

With reference to the relations (1.1) and (2.1), the reader may ask: why do we change the *greater than or equal to* sign by the *less than or equal to* sign? The reason is that E is energy and not energy uncertainty. If we had kept the *greater than or equal to* sign we would be saying that the energy of the force carrier particle could be arbitrarily high, that is, as high as we want, for example infinite. But we know that this is impossible. The energy of any particle, whether real or virtual, must always be finite.

Since the principle described by relation (2.1) refers to energy and lifetime rather than its uncertainties, we could be confused between relations (1.1) and (2.1). To avoid any confusion about these two relations, we shall call the relation (2.1): the *Heisenberg principle of temporary violation of energy conservation* or, in short, *the principle of violation of energy conservation*.

Let us now calculate the maximum energy, E_{max} , that the force carrier particle could have. To do this we shall use the relation (2.1). The maximum energy occurs when the lifetime of the particle is minimum. Mathematically this is expressed as follows

$$E_{max} = \frac{\hbar}{2 \tau_{min}} \quad (2.2)$$

According to the first postulate I introduced in another article [1], the minimum time with physical meaning is the Planck time (in this case time refers to lifetime). Its value is about: $T_P \approx 5.39 \times 10^{-44} S$. The Planck time is so small that it is impossible to imagine durations of that order. With this value, eq. (2.2) becomes

$$E_{max} = \frac{\hbar}{2\, T_P} \tag{2.3}$$

Where the Planck time is defined as

$$T_P = \sqrt{\frac{h\, G}{2\, \pi\, c^5}} \tag{2.4}$$

Now we shall calculate the maximum energy that the force carrier particle can have. To do this we replace τ_{min} in equation (2.3) by the second side of equation (2.4). This gives

$$E_{max} = \frac{\hbar}{2} \sqrt{\frac{2\, \pi\, c^5}{h\, G}} \tag{2.5}$$

$$E_{max} = \frac{h}{2 \times 2\, \pi} \sqrt{\frac{2\, \pi\, c^5}{h\, G}} \tag{2.6}$$

$$E_{max} = \frac{1}{2} \sqrt{\frac{h^2}{(2\, \pi)^2} \frac{2\, \pi\, c^5}{h\, G}} \tag{2.7}$$

Finally

$$E_{max} = \frac{1}{2} \sqrt{\frac{h\, c^5}{2\, \pi\, G}} \tag{2.8}$$

We now observe that the square root of this equation is the Planck energy. This energy is defined as

$$E_P = \sqrt{\frac{h\, c^5}{2\, \pi\, G}} \tag{2.9}$$

Hence equation (2.8) can be rewritten in terms of the Planck energy as follows

$$E_{max} = \frac{E_P}{2} \tag{2.10}$$

Thus, the maximum energy that a force carrier particle can have is the Planck energy divided by 2. If we want, we could shorten this equation even more by defining the reduced Planck energy, $E_{P\text{-}bar}$. This energy is the Plank energy divided by 2

$$E_{P\text{-}bar} = \frac{E_P}{2} \tag{2.11}$$

Combining the last two equations we have

$$E_{max} = E_{P\text{-}bar} \tag{2.12}$$

This means that the maximum energy that a force carrier particle can have is the reduced Planck energy. Let us write now the equivalent equations for mass.

$$M_{max} = \frac{M_P}{2} \tag{2.13}$$

Where

M_{max} = maximum mass of the force carrier particle
M_P = Planck mass

We also define the reduced Planck mass, $M_{P\text{-}bar}$, as the Planck mass divided by 2

$$M_{P\text{-}bar} = \frac{M_P}{2} \tag{2.14}$$

Therefore, from equations (2.13) and (2.14) we have

$$M_{max} = M_{P\text{-}bar} \tag{2.15}$$

3. Conclusions

In summary, we have proven that the energy-time Heisenberg uncertainty principle for a force carrier particle is the **Heisenberg principle of temporary violation of energy conservation.** Mathematically this principle is described by the following relation

principle of temporary violation of conservation of energy

$$E\tau \le \frac{\hbar}{2} \qquad (3.1) = (2.1)$$

The exchanged force carrier particle not only violates the conservation of energy but also the conservation of momentum. Thus, the momentum-position Heisenberg uncertainty relations for a force carrier particle is the **Heisenberg principle of temporary violation of momentum conservation**

principle of temporary violation of conservation of momentum

$$P_x x \le \frac{\hbar}{2} \qquad (2.2\ a)$$

$$P_y y \le \frac{\hbar}{2} \qquad (2.2\ b)$$

$$P_z z \leq \frac{\hbar}{2} \tag{2.2 c}$$

We have also found one of the meanings of the Planck energy:

> The Planck energy is twice the maximum relativistic energy that a force carrier particle can possess.

In other words, we may say that:

> The reduced Planck energy is the maximum energy that a force carrier particle can possess.

And, equivalently, we have found one of the meanings of the Planck mass

> The Planck mass is twice the maximum relativistic mass that a force carrier particle can possess.

and

> The reduced Planck mass is the maximum mass that a force carrier particle can possess.

Appendix 1
Nomenclature

I shall use the following nomenclature for the constants and variables used in this article:

c = speed of light in vacuum
h = Planck's constant
$\hbar$ = reduced Planck's constant $(\hbar = h/2\pi)$
ΔE = uncertainty in energy
Δt = uncertainty in time
E = total relativistic energy of a force carrier particle whose lifetime is τ
τ = lifetime of a force carrier particle whose total relativistic energy is E
τ_{min} = minimum lifetime of a force carrier particle
E_{max} = maximum relativistic energy of a force carrier particle
M_{max} = maximum relativistic mass of a force carrier particle
T_P = Planck time
L_P = Planck length

$E_P =$ Planck energy
$M_P =$ Planck mass
$E_{P\text{-}bar} =$ reduced Planck energy
$M_{P\text{-}bar} =$ reduced Planck mass
$P_x =$ momentum of the force carrier particle in the x direction
$P_y =$ momentum of the force carrier particle in the y direction
$P_z =$ momentum of the force carrier particle in the z direction
$x =$ position of the force carrier particle along the x axis
$y =$ position of the force carrier particle along the y axis
$z =$ position of the force carrier particle along the z axis

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REFERENCES

[1] R. A. Frino, *The Quantum Gravitational Cosmological Model without Singularity*, Section 3.1, p.5, vixra.org viXra: 1508.0203, (2011-2015).