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Review on Antimatter–The Future of Quantum Physics

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Abstract: ***This article is based on the study of antimatter, their behavior with the matter and their physical properties. We try to cover the most of the hypothesis, theories and paradox related to antimatter, their production and effect on the nature. This article clears your concept about annihilation-the vanishing act of antimatter, the gravitational effect and the trapping of antimatter. Antimatter can be the reason of the biggest blast after the big-bang in the universe or can be used to cure cancer and tumor. So the world of antimatter is really fascinating, let's have a look.***

Keywords: Antimatter, Positrons, Annihilation, Particle Decelerators, Penning trap

1. Introduction

Antimatter is material made up of antiparticles i.e. partners to the corresponding particles of ordinary matter. Acc. To theories it is said that the antimatter is created from the big-bang along with matter. The energy that came out during the big-bang later coagulated into matter and its opposite mysterious stuff "antimatter" in the perfect counter balance. This can be understand very easily- Suppose a child playing at the seashore trying to make a sand castle by digging the sand. In doing so he makes not only castle but a hole also, that hole is exactly like antimatter and the castle is the matter of visible universe. Ordinary Matter is the familiar stuff but antimatter identical in all respects (mass and physical properties) expect that deep inside its atom everything is back to front, positive to negative. Thus it have opposite electric charge and the quantum number like, a proton have positive charge while antiproton have negative charge also the electron with positive charge called positron. These are Antimatter-the antithesis to matter.

Today antimatter does not exist normally at least on earth because whenever a antimatter collides with a matter a vanishing acts happens and they both disappear resulting in ray of photons with no mass and just the packets of energy. This led to emission of enormous amount of energy. This process is called annihilation. We'll study about this in detail in coming sections.

Antimatter is unlikely to produce large amounts of energy that would interest power companies, so scientist starts making them artificially. Some of them succeed like CERN (European Organization for Nuclear Research) but the next challenge for them is how to keep the antimatter anywhere in lab because it collide with its container and might annihilated. We will study about the production and trapping of antimatter in further sections and also the uses & applications of this source of enormous power.

Till now many confusions and question would strike to your mind and some of them are quite obvious like,
Antimatter should have annihilated all of the matter in the universe after the big bang!
Antimatter might fall up!
Did antimatter hit earth?
The antimatter that prevented us from existing might shall be lurking in space!
Where should someone look to find antimatter?
How does antimatter can be created and stored in labs?
Keep these questions in mind and we are going to answer them all.

Particles are of three types:
1) Matter
2) Antimatter
3) Majorana particle

We are very familiar with matter, and going to take a tour of antimatter world in this whole paper and only thing that left is Majorana particle, it is a fermion that is its own antiparticle. The term sometimes used in opposite to a Dirac fermion[3] which describe fermion that are not there antiparticles accept "Neutrino" all of the standard model fermion are known to behave as Dirac fermion at low energy. The nature of neutrino is not yet settled, it may be either Dirac or Majorana. This is the topic of further research.

If antimatter exists elsewhere in the universe, then once in a while you would expect some to hit the earth. If this happen in our four billon year history, all signs will have long gone. But on 30 June 1908, a thousand mile east to Moscow, stretching from the arctic sea in the north of Mongolia in the south and from the Urals to Manchuria is a sparsely inhabited region larger than the whole Western Europe, at 8 o'clock in the morning a farmer notices a huge explosion in the air. He told investigators and scientists about a fireball so bright even make the sun appear dark and so hot that melted his silverware. Scientist later investigates more about this event and put a copy of this case under the antimatter explosions section.

This type of explosion recorded many times all over the globe, they might be the signs of something that comes from the space hitting our atmosphere and this type of explosion can only be possible by matter-antimatter annihilation. So the antimatter is closer to you than you think. Small amounts of antimatter constantly rain down on the earth in the form of cosmic rays, energetic particles from space. These antimatter particles reach our atmosphere at a rate ranging from less than one per square meter to more than 100 per square meter. Scientist has also seen evidence of antimatter production above thunderstorms. But other antimatter sources are even closer to home. For example Bananas produce antimatter. Yes its true, as bananas contains potassium-40, a naturally occurring isotope of potassium. As potassium-40 decays, it occasionally spits out a positron in the process. Our body also contains potassium-40 which means positrons are being emitted from you too. Antimatter annihilates immediately on contact with matter, so these antimatter particles are very short lived.

2. Asymmetry between matter-antimatter

The question that rise "Antimatter should have annihilated all of the matter in the universe after the big-bang" will now be answered.

The result of the spherically symmetrical Big Bang had to be equal amounts of matter and antimatter with the expectation of their mutual annihilation. The favoured explanation for that not happening is that the original symmetry was skewed in favour of matter and the universe is now all matter, the antimatter having annihilated with an equal amount of matter. This is just another case of "my infinity is greater than yours" here matter's infinity might be greater than antimatter's Infinity.

An alternative maintaining the original symmetry is presented. The logic and mechanism of mutual annihilation is analyzed and shows that a total mutual annihilation of original matter and antimatter could not have occurred. Our present universe must contain equal amounts of both forms of matter between some particles of which mutual annihilations can occur at a modest rate.

Current indication of detection of cosmic matter / antimatter mutual annihilations is Gamma Ray Bursts [GRB's]. However, the conviction that the universe is now all matter with no antimatter has left that possibility rejected and uninvestigated and left standing the massive supernovae core collapse hypothesis for GRB's.

It has recently been reported 4 that the rate of GRB's increases with red shift z over the range $z = 0 – 4$ as about $(1 + z)1.5$. That is, the indication is that the rate increases significantly with time into the past at least back to the time corresponding to $z = 4$ [and probably back to the Big Bang]. That finding is inconsistent with the massive supernovae core collapse hypothesis for GRB's and supports GRB's being cosmic matter / antimatter mutual annihilations.

So the only possible way to define this would be the asymmetry between the quantities of matter and antimatter at the time of big-bang.

3. Annihilation

In Particle physics Annihilation is the process of collision of a particle with its respective antiparticle. Acc. to $E=mc^2$ the total massenergy is conserved and whole mass of particle and antiparticle is converted into energy. For example

A positron colliding with electron (electron-positron annihilation) produces two photons with 1.022 MeV of gamma rays energy.

$$e^+ + e^- \rightarrow \gamma + \gamma \quad (1.022MeV)$$

Secondly annihilation of proton and antiproton is different from e-p annihilation because protons/antiproton consists of three types of quarks/antiquarks. During low-energy annihilation, photon production is favoured, since these particles have no mass. However, high-energy particle colliders produce annihilations where a wide variety of exotic heavy particles are created.

4. Production of Antimatters

1. Natural Production: Positrons and antineutrino are produce naturally by simple radioactive β^+ and β^- decays of the naturally occurring substance respectively. Antiparticle also created (or present) in the cosmic rays but they are less than 1% particle of cosmic rays. Many scientists discovered the antimatter in the thunderstorm and lighting. Basically these produce in the environment with sufficient high temperature. So it is possible the world of antimatter may be very hot and dense and full of antiparticles everywhere. This supports the statement of two parallel universes of matter and antimatter created at the time of big-bang.

2. Artificial Production: Positrons can be produce in lab by a laser drove electrons through a gold target's nuclei, which caused the incoming electrons to emit energy quanta that decayed into both matter and antimatter. This experiment led to produce highest amount of antimatter till now. Now CERN (also known as Antimatter Factory) is leading in the production of antimatter by artificially radioactive decay. They not only produce antimatter but also studies about the properties of antimatter. But study of antimatter is not so easy because to study its behavior we have keep it somewhere like in a container but as it collide with container walls it will annihilated and also we have to slow it down to study its gravitational nature. This led to the concept of antiparticle decelerator and antimatter trapping.

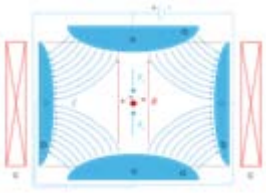
Antiproton Decelerator

The antiproton decelerator is a unique machine that produces low energy antiprotons for studies of antimatter. It consists of a ring bending and focusing magnets that keep the

antiproton on the same track while strong electric field slows them down. ELENA (Extra Low Energy Antiproton) is a new decelerator ring that will soon be commissioned.

Antimatter Trapping

Antimatter cannot be stored in a container made of ordinary matter because antimatter reacts with any matter it touches, annihilating itself and an equal amount of the container. To store the antimatter the device use is called penning tarp. It stores the charged particle using a homogenous axial magnetic field and in an inhomogeneous quadrupole electric field. This kind of trap is responsible to kept the antimatter in the centre of the container and prevent it to collide to container's wall.



But for uncharged particle a different setup is to be made. It includes the container of ever increasing magnetic field in all directions from centre to walls. This keep uncharged particle to be in the centre just like a marble in the centre of a bowl.

Gravitational Effects on antimatter

It is quite obvious for someone to think that if the all properties of antimatter are opposite to matter than unlikely to matter, antimatter might fall up. But According to Newton's gravity theory, the attractive force between the Earth and matter is

$$F=\frac{GMm}{R^2}$$

Where G is the universal gravitational constant, M is the mass of the Earth, m is the mass of the matter, and R is the distance of the matter from the centre of the Earth. The potential of gravity field of the Earth is $\varphi = GM/R$

The potential energy of the Earth gravity field is

$$U=\frac{GMm}{R}$$

Assume no energy dissipate to environment, due to energy conservation, the energy of photon before and after transformation into matter and antimatter is

$$E_{\gamma}^{total} = E_{e+}^{total} + E_{e-}^{total}$$

So the mass of generated matter and antimatter satisfies the following equation

$$m_{e+} + m_{e-} = E_{\gamma}/c^2$$

Taking mass of matter and antimatter similar and solve for energy mass equation we get

$$\frac{h\nu}{c^2} = m_{e+} + m_{e-}$$

If antimatter gravity is repulsive from matter, the Equation becomes

$$\frac{hvGM}{(c^2)R} = m_{e+}\frac{GM}{R} - m_{e-}\frac{GM}{R}$$

So it can be simplified to

$$\frac{hvGM}{(c^2)R} = 0$$

Above equation is paradox, it conflicts with that photon has potential energy in gravitational field, if the antimatter have no interaction with gravity field, Equation becomes

$$\frac{hvGM}{(c^2)R} = m_{e+}\frac{GM}{R} = \frac{hvGM}{2(c^2)R}$$

This Equation is paradox too, it also conflicts with that photon has potential energy in gravitational field and should be singularity at one place. So it can be concluded that the antimatter gravity must be positive, this means that the gravitational force between matter and antimatter is attractive and is same as that between matter and matter.

It is proved that the gravity between matter and antimatter is attractive, so with comparing the gravitational field produced by matter with the corresponding gravitational field produced by antimatter, some deductions can be made as follows:

1) The gravity field generated by antimatter is same as that generated by matter.
2) The gravity force is the interaction of matter with gravity field, according to Einstein's theory that the space-time is changed in gravity field
3) The interaction of antimatter with gravity field is same with matter.

Applications and Uses

Scientist says that antimatter is the costlier material to make on earth because it need roughly around $250 Million to produce 10mg of positron.

Medical: Antimatter could be use in PET (Positron Emission Tomography) that used to observe metabolic processes in the body. The system injects pairs of gamma rays that emits positrons into the body and a three dimensional image then constructed by computer analysis. Antimatter could also be use to cure cancer ant tumour because of its Vanishing act- Annihilation. We can direct inject the antimatter to the cancer/tumour affected cells to vanish them permanently but it could be dangerous to the body. It is the topic of further research.

Fuel: Matter- Antimatter collision can produce enormous amount of heat as Einstein suggest that $E = mc^2$, on this basis a rough calculation shows that 1 kg of matter and 1 kg of antimatter can produce 1.8×10^{17} J of energy. This is equivalent to approx. 40 megatons of TNT. Imagine this amount of energy as a propulsion system of interstellar/interplanetary travel. We can take a round of whole Milky Way galaxy in few hundred kilos of fuel. But we can't use it directly it needs special types of engines and propulsion system. I am currently working on this topic "How to use antimatter as a fuel" and surely come up with some good results.

Weapons: Not only fuel, but it can be use as a trigger and explosion which results in the production of deadliest weapon on the earth. It produces so much amount of heat that only few grams are enough to explode whole country. US Air Force already starts doing research on this topic.

5. Conclusion

Antimatter is one of the strangest substances that we notice. Its property and behaviour is purely the matter of further research. The production and storage of antimatter into the labs is much costlier so we need to finding out the way to store the antimatter that occurs naturally in nature and use it for the welfare of humanity. As the annihilation process of antimatter produce energy to have a trip around Milky Way it can be reason of biggest blast on the earth so be careful and behave gentle with antimatter. Antimatter has wide area of application and antimatter has the potential to be the most important discovery in nearby future.

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