

Electron identity in different environments

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(Peter Jakubowski; P.J.) Is there any evidence that an electron in liquid Helium must be identical to an electron in the centre of the Sun?

ChatGPT

(P.J.) There is no direct evidence that an electron in liquid helium must be identical to an electron at the centre of the Sun. The identity of electrons is based on the fundamental principles of quantum mechanics, which state that electrons that are in similar states are identical. However, electrons in different environments can exhibit different properties and behaviours depending on the forces and conditions they are exposed to.

(P.J.) For example?

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An electron in liquid helium behaves differently from an electron in the centre of the sun due to the special properties of this medium. In liquid helium, the electron is surrounded by helium atoms that are bound by weak van der Waals forces. This environment can influence the behaviour of the electron, e.g. through scattering and interaction with the surrounding atoms.

Extreme temperatures and pressures prevail in the centre of the sun, which strongly influence the behaviour of electrons. Electrons in such an environment can, for example, be strongly ionised by high temperatures and densities and be involved in nuclear fusion.

In both cases, however, electrons remain electrons in the sense of quantum mechanics, as they behave according to the laws of this theory and exhibit certain quantum mechanical properties.

(P.J.) Which ones, for example?

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Some basic quantum mechanical properties of electrons include:

Wave-particle duality: electrons can be both waves and particles, which means that they can be described by wave functions as well as their positions and momentum.

Quantised energy: The energy of an electron in an atom is quantised, i.e. it can only assume certain discrete values that are determined by the solutions of the Schrödinger equation for the respective system.

Spin: Electrons have an intrinsic spin, which is a quantum mechanical property. The spin can determine the direction of the magnetic moment of an electron and is an important factor in the description of electrons in magnetic materials or in the interaction of electrons with electromagnetic fields.

Pauli principle: The Pauli principle states that no two electrons in an atom can have the same set of quantum numbers. This leads to the formation of electron configurations that determine the arrangement of the electrons in the atomic orbitals.

These properties apply regardless of the specific environment in which the electrons are located and shape their behaviour according to the laws of quantum mechanics.

(P.J.) And the charge, and mass?

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Sorry for missing this important information. Charge and mass are two fundamental properties of electrons:

Charge: electrons have a negative elementary charge, which is approximately -1.602×10^{-19} coulombs. This charge is a fundamental property of the electron and remains unchanged regardless of the environment in which it is located.

Mass: The mass of an electron is approximately 9.109×10^{-31} kilograms. This is also a fundamental property of the electron and does not change depending on its environment.

These two properties are crucial to understanding electrons and are taken into account in various physical theories and experiments, regardless of their location or environment.

(P.J.) Who measured the mass and charge of an electron in the sun?

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The mass and charge of the electron have not been measured directly in the sun. Instead, these values are usually measured in controlled laboratory environments on Earth, where precise experiments can be carried out. The measured values for the mass and charge of the electron are universal constants that apply regardless of the environment.

The mass of the electron, for example, was determined by various experiments in particle accelerators and by precision measurements in electron traps.

The elementary charge of the electron has also been determined by various experiments, including Robert Millikan's oil droplet experiment, in which the charge of individual electrons was measured by observing electrical forces on tiny oil droplets.

These measurements were carried out in controlled laboratory environments to ensure the accuracy and reliability of the results.

(P.J.) But that's no guarantee that the charge and mass of the electron will always remain unchanged, is it?

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That is correct. Whilst the measurements of the charge and mass of the electron in controlled laboratory environments are very precise, there is no absolute guarantee that these values will always remain unchanged. However, it is important to note that the elementary charge and electron mass are considered fundamental constants of physics that are stable within the framework of known physical theories and principles.

Nevertheless, hypotheses about possible changes in these constants over time or under extreme conditions have been discussed in theoretical physics. However, such hypotheses are tested by experiments and observations based on current physical models.

So far, there is no experimental evidence that the charge or mass of the electron changes under normal conditions or in most environments. If new evidence or experiments indicate that these fundamental constants are variable, it would fundamentally change the foundations of physics and require new theories.

(P.J.) That's what I mean. I am suggesting that the charge of an electron is dependent on the state of the medium in which we have the electron.

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That's an interesting hypothesis. While there is no direct evidence that the charge of an electron is dependent on its state in the medium, there are concepts in physics that might suggest that the environment affects the properties of particles.

One example of this is the interaction of electrons with their environment in a material, which can lead to phenomena such as charge carrier density or effective mass. In certain materials, electrons can effectively exhibit a different mass or charge than in a vacuum due to the interaction with the surrounding atoms or other electrons.

However, such effects are usually limited to specific materials or environments and are explained by complex quantum mechanical phenomena. In general, however, the charge and mass of the electron are fundamental properties that apply regardless of the environment. Further research and experimental investigations are needed to better understand the possible effects of the environment on the properties of electrons.

(P.J.) Why are these investigations not of the highest priority, instead of claiming that electron charge and mass are invariant constants?

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The study of possible variations in the charge and mass of electrons is certainly an important topic in physics research. In fact, such investigations are actively carried out in various fields of physics, such as particle physics, solid state physics and cosmology.

The assumption that the charge and mass of the electron are invariant constants is based on decades of observations, experiments and theoretical considerations that confirm the stability of these fundamental properties. This assumption forms the basis for many calculations and models in physics and has proven to be extremely robust.

Nevertheless, the possibility of variation of these constants under certain conditions or in certain environments remains an interesting field of research that continues to be investigated. New experiments, observations and theoretical developments could further deepen our understanding of the nature of electrons and their properties.

(P.J.) No. Either they are constant, or they are variable. Not just once in a while.

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Sorry for the misunderstanding. You are correct. The question of the constancy or variability of the charge and mass of electrons is a fundamental and important question in physics.

So far, these quantities have been assumed to be constant because they have been confirmed with high accuracy in numerous experiments. Any significant change in these fundamental properties would have far-reaching implications for our physical theories and models, and therefore intensive research is being carried out to rule out or confirm this possibility.

If there were indeed evidence that the charge and mass of electrons are not constant, these effects would need to be carefully investigated to deepen their understanding and possibly reveal new physics beyond the Standard

Model.

(P.J.) I know of no such careful investigations, never heard of any, have you?

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Indeed, careful investigations into the possible variation of the fundamental constants, including the charge and mass of electrons, are an active field of research in physics. Some examples of investigations in this area are:

Precision measurements: Experiments in particle accelerators and laboratories to measure the charge and mass of electrons with ever-increasing accuracy.

Astrophysical observations: Studies of quasars, cosmic microwave background radiation and other phenomena in the universe to identify possible variations in fundamental constants over cosmic time.

Theoretical models: Development of theoretical models that predict variations of the fundamental constants in different physical scenarios and compare them with experimental data.

These research efforts are aimed at deepening our understanding of the fundamental laws of nature and investigating possible deviations from the previously assumed constants. It is important to note that such investigations are often very challenging and take time to produce meaningful results.

(P.J.) A concrete example, please.

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A concrete example of an investigation into the possible variation of fundamental constants is the "Oklo phenomenon". Oklo is a natural nuclear fission site in Gabon, Africa, that was active about 1.8 billion years ago.

Scientists have found that the natural nuclear fission that took place at Oklo resulted in the formation of specific ratios of uranium isotopes and fission products that are sensitive to possible variations in fundamental physical constants, in particular the fine structure constants and the mass of neutrons.

The study of isotope ratios and fission products from the Oklo phenomenon allows researchers to set limits on possible variations in these constants over the billions of years of Earth's history.

These studies are an example of how the analysis of natural phenomena can be used to place constraints on possible variations in fundamental physical constants.